IMPROVING DECISION QUALITY IN URBAN STORM WATER MANAGEMENT PROJECTS BY USING THE 3DI SYSTEM

Floor Speet

s0202568

Master thesis

Master Civil Engineering & Management

Track Water Engineering & Management

October 2014

UNIVERSITY OF TWENTE.

Subject:	Master thesis
Name:	Floor Speet
Email:	floorspeet@gmail.com
Date:	02-10-2014
University:	University of Twente
Supervisors University:	Dr. Ir. M.J. Booij
	Dr. M.S. Krol
Company:	Nelen & Schuurmans
Supervisor company:	Ir. Jorik Chen
Study:	Master Civil Engineering & Management
Track:	Water Engineering & Management

UNIVERSITY OF TWENTE.

Nelen & Schuurmans

Source of the picture on the front page:

http://www.innovatie.waternet.nl/wp-content/uploads/2012/05/Tramwateroverlast-Meester-Treublaan7-1024x768.jpg

Summary

Climate change will lead to more extreme rainfall in cities. Together with urbanization, this will lead to an increased chance of flooding in cities. Measures should therefore be taken in the urban environment. Important is the decision about which measure will be implemented, a water simulation model can be helpful for this. The use of a water simulation model for this decision can possibly increase the decision quality. However, there is a lack of knowledge about the effects of the use of a model on the decision quality. The objective of this study is therefore to assess the impact of using a water simulation model on decision quality in urban storm water management projects. The studied water simulation model is the 3Di system. 3Di Waterbeheer is an instrument that can visualize flooding processes in 3D and can calculate the effectiveness of measures.

The main research question is 'What is the difference in decision quality of urban storm water management projects as Rainproof in Amsterdam caused by using detailed, quick and interactive models as the 3Di system in comparison to the current decision quality of these projects?'. Amsterdam Rainproof is a program that aims to make the city of Amsterdam more Rainproof in the future. The main question is answered by first studying the current situation of decision-making in urban storm water management projects (sub question 1). After this the decision quality while using the 3Di system is identified for these projects (sub question 2). Finally, the decision quality while using the 3Di system is compared with the decision quality of the current situation (sub question 3).

The research questions are answered with a range of methods. Interviews are held to obtain information about the current situation of decision-making and about decision-making processes. After this, two cases are used to execute workshops. One case is a project in the Rivierenbuurt in Amsterdam, water management measures can be integrated in the redesign of a main road. The other case concerns the Houtmankade in Amsterdam. This is a low-lying area where adaptations are needed for future rainfall. Decision-makers from the municipality and the water board are brought together in these workshops to discuss about measures and evaluate the measures with 3Di. The most important workshop result is the questionnaire that is filled in by every participant. The decision quality of the process using 3Di is measured in the workshops by using eleven decision quality elements. Besides that, the decision quality difference between a process with and without 3Di is measured in the same way.

The study has found that models are not often used in the current situation of decision-making in urban storm water management projects. Stakeholders discuss about the public space design by e-mail and standardized designs for water management are used. The use of the 3Di system is therefore mostly compared in this study with no model use in the decision-making process. The study has shown that the use of the 3Di system increases the decision quality on all elements. This is also valid when the decision-maker was using another water simulation model in their reference situation. The three decision quality elements that were most improved by using 3Di were the coherence of alternatives, the consciousness of the decision-makers perspectives and the understanding of the consequences of alternatives. The level of detail of alternatives was least improved. In addition, the decision quality of using 3Di itself was rated high. The use leads to a high understanding of the consequences of alternatives and was easy to use according to the participants of the workshops.

Preface

This is the master thesis of my master Civil Engineering and Management, track Water Management and Engineering, at the University of Twente. During the graduation period, I worked mostly at Nelen & Schuurmans Utrecht. In addition, I had several meetings about the cases at Waternet in Amsterdam.

I would like to thank the colleagues of Nelen & Schuurmans for the time they took to explain me the 3Di system. Besides that, the lunch walks were a good way to interrupt the working day. Especially, I would like to thank Jorik Chen for his useful comments and discussions about the thesis. Besides that, I appreciated the help and enthusiasm for the workshops from Eljakim Koopman and the others from Waternet that helped me.

Many thanks for the help of the supervisors from the university, Maarten Krol and Martijn Booij. The advice and flexibility was very helpful during the process.

Finally, I would like to thank my family and friends that helped me with nice distraction from the thesis. I would particularly thank Peter Schoonderbeek for the good advices and patience during the graduating period. Besides that, I want to thank my parents for the opportunity and incentive to study.

Contents

Definitions

3Di system	An integrated water management system of the 3Di consortium that focuses on speed, accuracy, integration and interaction (Nelen & Schuurmans, 2014). Separate 3Di model can be created for different locations and purposes.
Alternative	One of the possibilities in a decision. In this research an alternative is a storm water measure, for example green roofs. An alternative can also be a combination of different measures.
Amsterdam Rainproof	Urban storm water management project in Amsterdam executed by the municipality of Amsterdam and Waternet. The term 'rainproof' is defined as a situation in which the hindrance of storm water is acceptable for all stakeholders.
District councils of Amsterdam	Seven district councils in Amsterdam have the responsibility over the important decisions in their own assigned neighborhood. An important is the management of public space, as road renewal and maintenance of squares.
Climate change	Future change in climate. This research focuses especially on rainfall pattern changes due to climate change
Decision-making process	The process in which stakeholders decide about a solution for a problem. In this research this is the decision about which measure will be taken for urban storm water. This contains the whole process, from initial problem until implementation.
Decision quality	Quality of the process, final decision and input of information of the decision-making process, evaluated using a framework. Decision quality is different from the quality of the outcome (Keisler, 2011).
Decision quality elements	Elements in which decision quality can be divided. These elements are further divided in sub elements.
Effects (of measures)	The effects of measures after implementation, in this research this especially focuses on a reduction of storm water.
Mainstreaming	Combining climate change with other (socio-economic) drivers (Gersonius et al., 2012). The main focus of a projects is in that case not water management, but water management is integrated in another project. The Dutch term used is 'meeliften'.
Public participation	The direct involvement of the public in decision-making. In addition, the term 'public involvement' or 'stakeholder participation' is sometimes used instead of public participation (Giupponi et al., 2006).
Storm water	Direct rainwater runoff
Urban storm water management project	Project where solutions and measures for a storm water problems in urban environments are searched.

Urban resilience	The robustness and rapidity of a city as a system to react by adaptation or mitigation on, for example, flooding (Lu & Stead, 2013).
Waternet	Organization that performs the executive tasks related to water of the municipality of Amsterdam and the water board Amstel, Gooi en Vecht
Water simulation model	A representation or imitation of reality in which water flow is simulated. In this research this is about the flow of water over a surface or through the ground.

1. Introduction

This chapter introduces the study subjects, objects and objectives. Section 1.1 describes the motivation of the study. Section 1.2 gives information about the decision-making processes and decision quality. Section 1.3 introduces the problem and hypothesis of the study. Section 1.4 describes the study objects and objective further. Section 1.5 gives the main and sub research questions. Section 1.6 outlines the structure of the remaining part of the report.

1.1. Motivation of the research

Future climate change and urbanization will lead to more problems with urban flooding (Hammond et al., 2013). Climate change will affect rainfall patterns in the whole world, this will especially give problems in cities because of the high density of paved areas. Unfortunately, there is much uncertainty about the impacts of climate change, due to both uncertainty in climate projections and uncertainty in hydrological models (Arnbjerg-Nielsen et al., 2013). Most global conclusions on climate change predict an increased average earth temperature and sea level rise. For the Netherlands this will result in more extreme rainfall events in the summer. The average sum of rainfall will increase with 5-27% in 2050. In the winter, the sum of rainfall will increase with 4-14 % in 2050. The intensity of rainfall events will increase also due to climate change. For 2100 these percentages will be even higher than for 2050 (Dorland & Jansen, 2007). The future impact of measures reducing climate change effects is thus uncertain because the uncertainties in climate change. The worldwide urban population is expected to grow from 3.6 billion in 2011 to 6,3 billion in 2050. This will result in more impervious areas, increased urban runoff and higher exposure to flood hazard in cities (Hammond et al., 2013). For example, it is expected that the intensity of rainfall will increase in the future in Amsterdam, while the paved area will increase due to more dwellings (Uittenbroek et al., 2013).

Figure 1: Flooding of the Rijnstraat on July 28th 2014 (source: Frederique @fevroom)
Figure 2: Flooding of a street close to the Rijnstraat on July 28th 2014 (source: Ruben Steeman)

The hindrance of floods in cities is relatively high because of the high density of people and concentration of economic activities (Heikkila & Huang, 2013). Urban flooding can have negative effects on many activities, such as education, employment and traffic. This can lead to financial losses in a city (Hammond et al., 2013). Because of this, cities should be more resilient for flooding and should be capable to adapt easily and rapidly to changes (Lu & Stead, 2013). Climate change and thereby an increase of rainfall is an example of these changes. In Figure 1 and Figure 2 flooded streets in Amsterdam are displayed, the water hindrance was caused by very heavy rain on the 28th of July 2014.

In many cities around the world projects have started to increase the urban resilience (for changes as climate change) and Amsterdam is one of these cities. The project Rainproof has started in January 2014 and it will contribute to both current storm water bottlenecks and mainstreaming of storm water strategy in the city in the future (Uittenbroek et al., 2013). An important part of these storm water management projects is the choice between possible measures. Decisions made in urban storm water management projects may rely on predictions of rainfall, the effects on the city and the expected effects of measures. These predictions can be made with a flood simulation model. More accurate and detailed predictions can lead to a higher decision quality and thereby hopefully less storm water hindrance.

Flood simulation models are increasingly detailed and quick because of increased possibilities with computers (Hammond et al., 2013). Frank Tibben and Anne Leskens (Leskens et al., 2014) are currently doing research about the decision-making process and the use of models in flood disaster management and urban storm water management projects. They are both doing this research for the University of Twente (as respectively master thesis and PhD thesis) and Nelen & Schuurmans. The study of Leskens et al. (2014) concentrates on flood disaster management. The other study concentrates on improvements by changing the decision-making process itself. No research about the effect of the use of a water simulation model for decision quality in storm water management projects is done.

1.2. Decision-making

This study focuses on the decision-making process of urban storm water management projects. A description of the decision-making process and how to optimize the outcome is given in this section.

1.2.1. Decision-making process

The decision-making process is described in literature with different frameworks. Many authors make the distinction between a process with a clear start and end and a process with repetition of some steps. Hommes (2008) describes this as the rounds model and the phase model. The phase model (also called analytical decision-making) has different phases that follow on each other. The rounds model (or participatory decision-making) consists of rounds with a decision at the end, so more small (but crucial) decisions are made. A complex participatory decision-making process can better be seen as a rounds model in which different decision-making rounds are passed. Actors can contribute each round and can change the content and directions of the total process (Hommes, 2008). Mintzberg (1976) describes a different representation, with distinct phases that are not sequentially related and can individually be passed several times. Grünig & Kühn (2009) uses sequential phases, but going back to an earlier phase is done often.

The phase model is used in this study to describe the decision-making process. The categorization of the phase model gives a clear distinction between the different steps of the decision-making process. The rounds model consists of steps that cannot be distinguished so easily, because the content of the rounds depends highly of the specific process. The phase model of Bredenhoff-Bijlsma (Bredenhoff-Bijlsma, 2010) and Hommes (2008) is combined with the representation of Grünig & Kühn (2009). This results in the representation in Figure 3. The next sections describe the steps and input further.

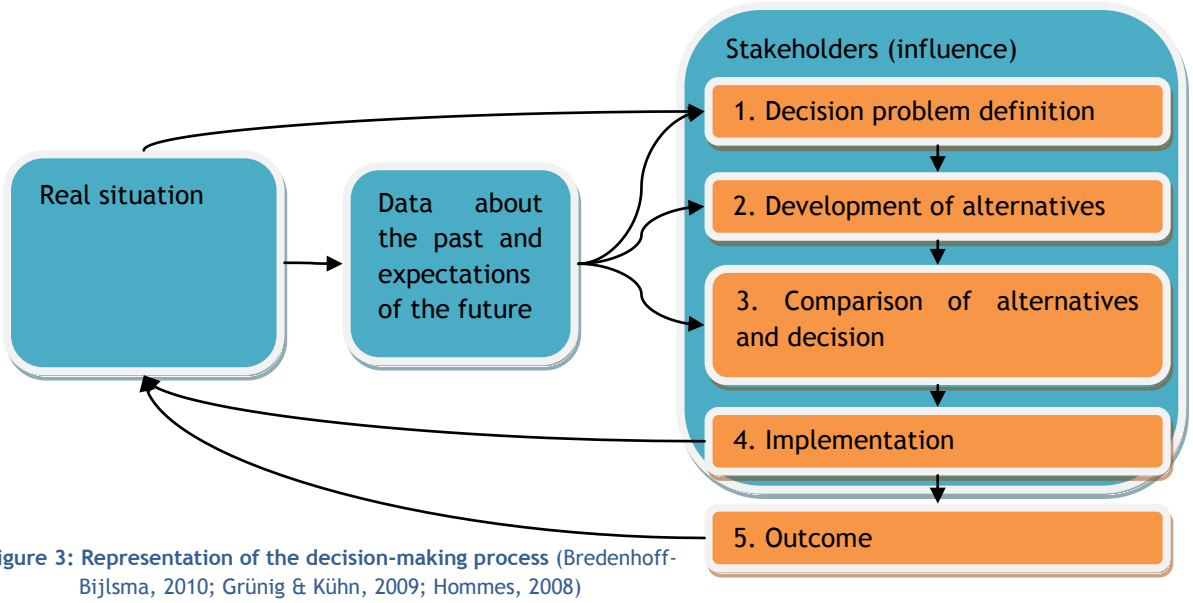


Figure 3: Representation of the decision-making process (Bredenhoff-Bijlsma, 2010; Grünig & Kühn, 2009; Hommes, 2008)

The problem of a decision-making process comes from the 'real situation'. At the end of the process, the real situation is changed, depending on the decision made. In addition, data about the past and expectations about the future are important input of the decision-making process (Lu & Stead, 2013). These are important for the formulation of the problem, formulation of alternatives and the comparison of alternatives. Expectations can be trends or threats and are often determined using a model or other ways of data interpretation. The stakeholders perform step one until four in the decision-making process, although this are not always the same stakeholders for each step.

Steps in the decision process are; the decision problem, development of alternatives, comparison of alternatives and decision and implementation, see Figure 3. During the step 1, the decision problem definition, the decision is defined and criteria for the result are set (Hommes, 2008). Knowledge about the current situation and the stakeholders is needed for this. The second step is the development of alternatives. Alternatives affect mostly different disciplines, this is the case for urban water management projects because integration is an important aspect. Storm water concerns both the drainage and aboveground disciplines. Besides that both private and public buildings, roads, parks and tunnels can be affected (Kluck et al., 2013). The third step is the comparison of effects of alternatives and the decision. The effects of measures can be determined in detail with a model, so a flood simulation model can be helpful for this. Although, alternatives can also be compared on other fields of interest than effects on storm water. A shared vision between the stakeholders is important to reach a collective decision. Public participation can contribute to a this. In addition, participation can ensure that a measure will be acceptable and executable (Huitema et al., 2009). Furthermore, public participation can be important for the implementation (step four) because it improves the legitimacy and accountability of decision-making (Huitema et al., 2009). The implementation is the realization of the chosen alternative what affects the situation of the world. The last step is the outcome, which is not influence by the stakeholders but by other factors. The outcome is the result of the implementation, how well the alternative reduces the problem and what the effects are on other aspects.

1.2.2. Decision quality

It is desired to have a good outcome or a good decision in most decision-making processes. Many different definitions of 'a better decision' are used in literature. Ramos et al. (2013) state that it depends on economic benefit, "better decisions are those that provide the most economic benefit" (Ramos et al., 2013, p. 2230). In health care a better decision is obtained when the client understands the decision and had the possibility to ask all his/her questions (Fraenkel et al., 2011).

Arvai & Froschauer (2010) states that whether one decision is better than another decision is determined by the quality of the decision and the decision process.

However, the desired result of a decision-making process is a good outcome, what is different from a good decision according to many authors. Figure 4 presents one theory, which is followed in this research. The decision is made by using information, values, alternatives and combining these with logic. The decision is then the final choice, the outcome is what occurs after this choice (Mcnamee & Celona, 2008). Howard (2007), Mcnamee & Celona (2008) and Keisler (2011) state also that decision and outcomes are different because alternatives that were not chosen cannot be tested on quality. Besides that, effects of the outcome are not known when the decision is made. Arvai & Froschauer (2010) states that outcomes are often seen as part of the decision quality, because people judge a decision on the effects is has. Arvai & Froschauer (2010) argue that this is not right because even the 'best' decision-making process can results in bad outcomes. In their research lay people evaluated the decision quality more on the outcomes than on the decision-making process.

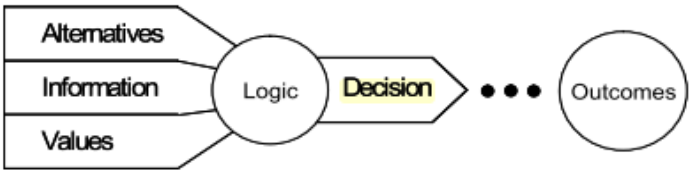


Figure 4: Representation of decision-making process (Mcnamee & Celona, 2008)

Because the quality of the outcome cannot be determined, the quality of the decision should be measured by the chance on a good outcome (Mcnamee & Celona, 2008). The chance on a good outcome increases when the quality of the decision-making process is higher.

1.3. Problem statement and hypothesis

One part of the project Rainproof Amsterdam is the comparative assessment of different measures that will be implemented (step 3 in Figure 3). These decisions should be made by all stakeholders of the storm water problem in the city; governmental institutions, companies and inhabitants. The implementation of the Rainproof program can possibly be improved by using a detailed flood simulation model as the 3Di system to compare alternatives and make a decision. An improvement for a project can be obtained when the result of the chosen decision is better. However, good decisions can lead to bad outcomes or results after implementation. The decision process can be independent from the outcome of the decision. The outcome is only a future result that cannot be tested on quality beforehand (Howard, 1988). The quality of the decision can thus only be maximized to increase the chance on a good outcome. This quality might be increased by using a water simulation model. However, there is not much research done about the difference in decision quality due to water simulation model use. The problem statement is therefore:

There is a lack of knowledge about the effects of using a water simulation model on decision quality in urban storm water management projects.

1.4. Research objective and research questions

This section describes the objective, scope, research model and research questions. Figure 5 gives an overview of the research model. The decision quality of urban storm water management projects is assessed with the test cases using or not using the 3Di system. The boxes in Figure 5 are further explained in the next sections.

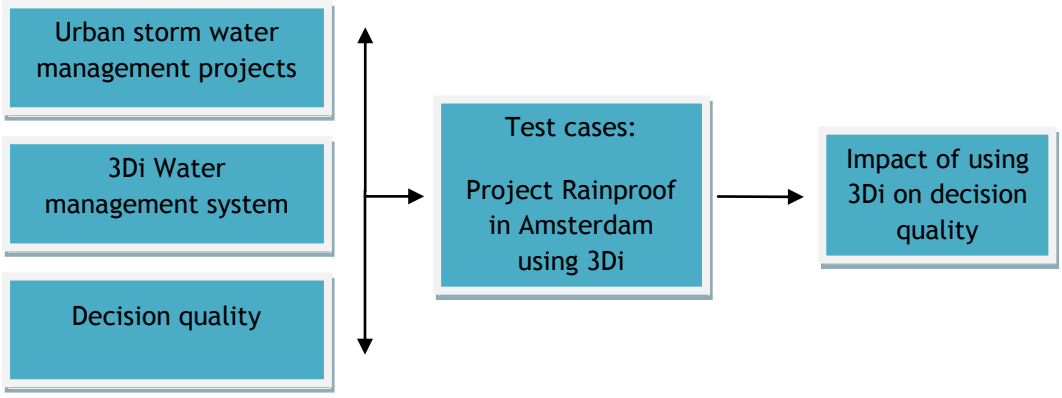


Figure 5: Research model

1.4.1. Research objective

The research objective is to assess the impact of using a quick, detailed and interactive water simulation model as 3Di on decision quality in urban storm water management projects.

1.4.2. Research scope

The research focuses on the decision-making process of urban storm water management projects. Decisions are made between possible measures for addressing storm water problems, taken by either organizations or individual people. The research focuses on step 2 and 3 from Figure 3, development of alternatives, comparison of alternatives and the decision between alternatives. These steps are expected to be influenced by water simulation models as 3Di and are affecting the decision quality. The implementation and outcome are not affecting the decision quality because these steps are occurring after the actual decision. An important aspects of the studied projects is the connection to other projects (‘meeliften’). Such projects are not sole projects, but join other projects and insert water management in these.

The research focuses on urban storm water management. Flood disaster management is not studied. Focus points of flood disaster management projects are emergency management and rehabilitation of floods (Akter & Simonovic, 2005), besides that decisions have to be made in a very short time. These situations can possibly occur in an urban environment, but occur mostly in locations outside cities.

The quality of the decision procedure is not considered in the research, but is seen as a fixed factor. This includes the knowledge of the decision-makers, the compilation of the group decision-makers and for example the setting and location of the decision process. Stakeholders of the decision-making process in urban storm water management projects are governmental organizations, as the municipality of Amsterdam and Waternet, companies, but also inhabitants. The stakeholders of a specific project location depend on the scale of the problem and measure. Stakeholders in this research are governmental organizations as Waternet, district council and the city service of traffic and transport. Inhabitants are not directly involved.

1.4.3. Research objects

The research objects are urban storm water management projects and water simulation models. The program Amsterdam Rainproof is used as a test case for urban storm water management projects. The 3Di system is used as an example of water simulation models. The functionalities of the 3Di system are leading for the functionalities of a water simulation model in this study. This research will contribute to these projects by finding opportunities of integration of the 3Di system in the Rainproof program, proving a broad application of the 3Di system and increasing awareness about Rainproof. More information about urban storm water management projects as Amsterdam Rainproof and water simulation models as 3Di is given in the next sections.

Urban storm water management projects

Urban storm water management projects are projects in a city where water management is involved. Due to more and more intense rainfall in the future, storm water measures should be integrated more in urban projects. Water management is mostly not the main purpose of these projects, but for example the redesign of public space or reducing traffic problems. Some cities in the Netherlands (for example Amsterdam and Rotterdam) are setting up programs to integrate water management projects in other projects in the city. The projects of Amsterdam Rainproof are used as example of urban storm water management projects in this study. Amsterdam Rainproof is a temporary program with the goal to make Amsterdam more vulnerable to extreme rainfall by initiating the integration of water management in other projects. It is expected that projects in other cities have many similarities to Amsterdam Rainproof and the projects belonging to it.

Water simulation models and decision-making tools

Models can be used to predict the impact of alternatives to assist the comparative assessment between alternatives. The advantage of models is that they can describe complex relationships and deal with large amounts of data. Models have been proven to be successfully in creating awareness of measures for lay people and other stakeholders.

According to many authors models are not always used in decision-making processes. Limitations in calculation time and flexibility of flood simulation models cause reduced advantages of model use. Another argument of not using a model is uncertainty about the model results. Therefore in some decision-making processes rules of thumb are used rather than models (Leskens et al., 2014). The uncertainty of the model results is partly caused by miscommunication between scientists, who make the model, and the practitioners. On this can be anticipated by more collaboration between the scientists and the practitioners, the scientists have to listen better to the practitioners wishes and knowledge to decrease the uncertainty of model results (Morss et al., 2005). Disadvantages of decisions based on models are the objectivity of scientific models, they can only be validated after the decision is implemented. Besides that, not all stakeholders will accept the results of the model. When participatory modeling is used, that means that modeling is done with a constant dialogue between stakeholders and experts, model results are seen as more relevant and reliable (Craswell et al., 2007). To overcome these problems with model use, new models are developed.

Models found in literature are the D-PHASE model, hydrological models based on GIS, participatory modeling, WOLK, the 3Di system and the Decision Support System AQUATOOL. This is not a complete collection of water simulation models but can serve as an overview of different kind of models. The D-PHASE model is a web-based visualization platform for hydrological data and predictions in the Alpine region. Frick & Hegg (2011) concluded that the use of such a model can contribute to the understanding and knowledge of information by different stakeholders. Hydrological models using GIS, as TOPMODEL or MODFLOW combined with GIS are also improving the visualization, understanding and collaboration between decision-makers (Al-Sabhan et al., 2003). Another kind of model is adaptive modeling, using a model different in the decision-making process. The consensus between groups of decision-makers will increase by using this method (Voinov &

Bousquet, 2010). AQUATOOL is a model that suggests a decision for problems in river basins in Spain, based on the input of stakeholders. This model affects the communication between decision-makers, reduces the complexity of the decision and eases the setting of priorities (Andreu et al., 1996). WOLK is a quite new model for water simulation on the street and is currently used in the Netherlands. WOLK calculates overland flow based on precipitation and surface elevation (DEM). The output of the tool is a map with an overview of locations with needed water storage (Klok, 2012).The newest model is the 3Di system, this model is studied in this research because it uses the current possibilities of computer calculation and is interactive (in contrast to most models described before). Besides that, the model is calculating very fast and is still detailed (Nelen & Schuurmans, 2014).

TU Delft, Deltares and Nelen & Schuurmans develop the 3Di system. 3Di Waterbeheer is an instrument that can visualize flooding processes in 3D and can calculate the effectiveness of measures (Ven, 2012). It can assist the designer with knowledge about expected damage and risks. The 3Di system focuses on a short calculation time, a high level of detail and visualization for also non-technical people (Nelen & Schuurmans, 2014). The startup of 3Di has been ended in April 2014, so 3Di can be used for flooding projects now. The model will be developed further by including more functionalities (as a sewage module). A case study in West-Friesland showed that 3Di is useful for flood risk scenarios and damage calculations (Nelen & Schuurmans, 2013a). The 3D-visualizations in the case study were supporting the commitment of stakeholders (Nelen & Schuurmans, 2013a). Figure 6 shows the appearance of the 3Di system.

Figure 6: Print screen of the 3Di background system, with a map the area around Amsterdam Houtmankade

1.5. Research questions

The main question is:

What is the difference in decision quality of urban storm water management projects as Rainproof in Amsterdam caused by using water simulation models as the 3Di system in comparison to the current decision quality of these projects?

The main question will be answered with help of three sub questions:

1. **What is the current situation of decision-making in urban storm water management projects?**

Improvement can only be measured when the reference situation of decision-making is known. The reference situation or current situation of decision-making consists of the steps and tools used nowadays in decision-making. Also the stakeholders and interaction between them is important.

2. **What is the decision quality using the 3Di system in urban storm water management projects?**

The decision quality of using the 3Di system itself can point out the weak and strong points of the model. This information can help to identify on which points the use of the 3Di system can improve the decision quality.

3. **What are the changes in decision quality elements in urban storm water management projects caused by using the 3Di system in comparison to the current decision quality in these projects?**

In comparison to older models or without using a model, the 3Di system is said to be more detailed, quicker and more interactive. Using the 3Di system might improve therefore the decision quality, but no research has been done about that.

1.6. Report outline

The methodology of answering the sub questions and main question is described in the next chapter, Chapter 2. The results are given in Chapter 3. Chapter 4 discusses the results and the methodology. Chapter 5 concludes with the answers on the research questions and gives recommendations for further research and the involved projects.

2. Methodology

This chapter describes the methodology used in this research. Section 2.1 describes the methodology per research (sub) question. Section 2.2 explains the cases used. Section 2.3 gives the measurement method for the decision quality elements. Section 2.4 describes the interview method and the interviewees. Section 2.5 describes the workshops executed for the cases and the questionnaires held during the workshops. Section 2.6 describes the 3Di system used.

2.1. Overview per research question

The main question of the study is:

What is the difference in decision quality of urban storm water management projects as Rainproof in Amsterdam caused by using water simulation models as the 3Di system in comparison to the current decision quality of these projects?

The main question is answered by combining the sub questions. Possible improvements of using the 3Di system in these projects can be derived from the decision quality. This is both the decision quality of 3Di and the comparison of decision quality with the current situation. An graphical overview of the method can be found in Figure 7. The sub questions are answered as following:

1. **What is the current situation of decision-making in urban storm water management projects?**

The current situation of decision-making is determined mostly by interviews (see section 2.4 and Appendix B). A small part of this question is answered with information from project reports and meetings attended during the research period (see Appendix B). The current or reference situation can differ for different people. The following information about the current situation is needed:

- Description of the steps taken in the decision-making process
- Stakeholders involved in the decision-making process
- Model use in the decision-making process
- Requirements of information used in the decision-making process (needed for workshop setup)

2. **What is the decision quality of the 3Di system used in urban storm water management projects?**

For each case (see section 2.2), a workshop is held (see section 2.5). The decision quality of 3Di is determined by the opinion of the workshop participants. The decision quality is split up in decision quality elements for measurement. The decision quality elements and their measurement method can be found in section 2.3. As preparation for the workshop and additional information about the decision quality, some interviews were held (see section 2.4). For the workshop the 3Di system is used, a description of the 3Di model can be found in section 2.6.

3. **What are the changes in decision quality elements in urban storm water management projects caused by using the 3Di system in comparison to the current decision quality in these projects?**

The possible improvement of decision quality is measured similarly to sub question two (decision quality of 3Di). However, the decision quality of the current situation is compared for this question with the decision quality using the 3Di system. The comparison is made by asking the opinion of the participants about the differences between the setting of the workshops (3Di) and their reference situation. In this way, the differences in decision quality between their current situation and the

use of 3Di in the process can be identified. In addition, interviews are held to determine the decision quality more accurate.

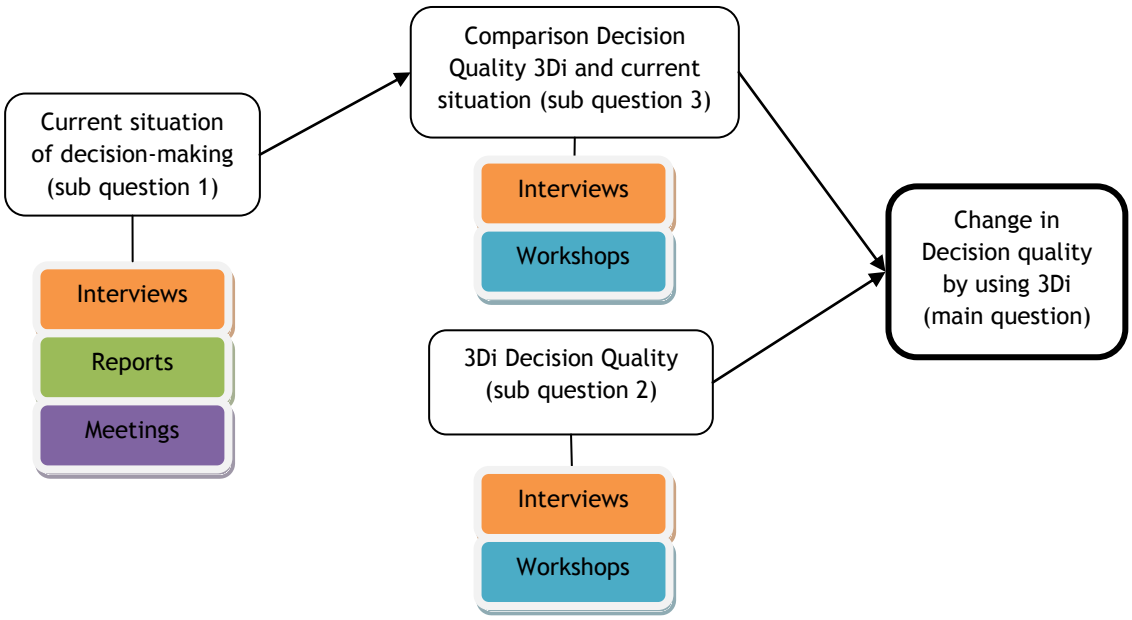


Figure 7: Overview method

2.2. Cases

Two cases are studied in this research, case Rivierenbuurt and case Houtmankade. Both cases are projects in Amsterdam with future water management issues. In both areas, water management should be integrated in other project according the Amsterdam Rainproof program. The cases were selected because they were current projects, the decision process has already started. The study contributes thus to the projects and stakeholders are already known. The Amsterdam Rainproof program is firstly described in this section, afterwards, the both cases are described.

2.2.1. Program Amsterdam Rainproof

The municipality of Amsterdam is implementing the program Rainproof in the city. Amsterdam Rainproof is a program that initiates a movement that makes the city gradually rainproof. The program has started in January 2014 and will last for one and a half year. The reason for the program is the increasingly vulnerable city due to climate change in combination with urbanization. The long-term goal is to have a rainproof city in 2050. Rainproof does not have quantifiable goals (as no water on the street for a certain amount of rain). The goal (for 1.5 year) is to make the city more rainproof by the following changes:

- increasing awareness and insight in the way of possibilities of contribution for everyone in the city
- adding value by smart investments in small solutions that use rainwater to solve other problems, this will make the city greener and more livable
- integrating a rainproof way of thinking in public organization
- dealing better with rainwater and reducing storm water damage by increasing the sponge-effect, solve bottle-necks and protect valuable objects better

The program approach focuses on networking, communication and mainstreaming. Networking means the active involvement of inhabitants, housing corporations, administrators and officials of the municipality, district organizations and initiatives and entrepreneurs. Communication implies that Rainproof will be a known and visible project. Mainstreaming involves dealing naturally with extreme rainfall, even when the project is finalized (Amsterdam Rainproof, 2014).

The decision-making process of the Rainproof program is defined as a participatory approach. Stakeholders of the problem and especially inhabitants are very important for the Rainproof program, Rainproof should be an open proactive platform. The problem of extreme rainfall concerns not only public areas but also private areas. Rainproof will focus therefore on integration of different disciplines and stakeholders, both the municipality, companies and private people (Uittenbroek et al., 2013). The project team Rainproof is trying to reach the highest level of involvement, self-control, by the end of the startup period. However, this is not possible to include in this research. With self-control and many stakeholders, the workshop would have been difficult to organize and no structured answers could have been obtained.

For the Rainproof program the goal is set by the project team, location specific goals have to be set by the other stakeholders. After this, alternatives are developed. For the Rainproof program, the project team or experts mostly set the alternatives and other stakeholders can bring up additional alternatives. The Rainproof program does not aim to implement large measures in the Rainproof program, but to integrate the concept in future projects. The urgency is not very high, but the city has to be prepared for rainfall related problems. Another important aspect of Rainproof is integration of different disciplines, besides a solution for the rain problem measures can also contribute to other aspects of the city. These aspects of Rainproof are tried to integrate in the research by proposing measures in line with the Rainproof program. These are thus relative small measures that reduce also other problems in the city.

Recently, a study about locations vulnerable for flooding by extreme rainfall in Amsterdam was done. This study was not very detailed, but an idea of problem locations could be acquired. A location is vulnerable for this study by a combination of water problems and budget needed to solve the problems. The study stated that the centre of Amsterdam was most vulnerable. After this the Vondelpark area and Oudzuid (with the Rivierenbuurt located inside) were also seen as vulnerable. This was done with an analysis with WOLK (a model from Tauw), whereupon the results were checked by field observations (Habes et al., 2014).

2.2.2. Case Rivierenbuurt

The case Rivierenbuurt focuses on the Rijnstraat and surrounding streets. The problem is the water management on the Rijnstraat. Water from the higher southern part of the Rijnstraat flows to the lower part of the Rijnstraat (north wise). The Rijnstraat is enclosed by buildings on two sides, except some small side roads. It is expected that the street and the surrounding streets will flood by extreme rainfall events. The case will focus on the Rijnstraat because constructions works will be executed between 2014 and 2016 on the south side of the Rijnstraat. The road design will be changed, detached cycle roads will be constructed, thresholds will be placed and the tramway will be removed. At the same time cables and pipes will be reconstructed (“Rijnstraat-Zuid - Stadsdeel Zuid,” n.d.). The effect of a 100 mm rainfall event in one hour is presented in 3Di in Figure 8.

Figure 8: Rijnstraat after a rainfall event of 100 mm in 1 hour

The Rivierenbuurt is a district in Amsterdam Zuid. The main part of the area has been build between 1920 and 1940 for the middle or upper class people. The architect was H.P. Berlage and the areas has been build thus in the style of the Amsterdamse School. This style results in a lot of stone, both in buildings and pavements, and semi-high buildings with a large surface area. Only a small part of the area is green, the largest part is paved.

3Di can be helpful in identifying and quantifying the possibilities of storm water solutions in the road design. The road design has already been finished, but still small changes can be made. The 3Di workshop can also be an eye-opener for the participants about the integration of Rainproof thinking in the design process. Even when the design of the road cannot change enough to perform as an ideal design for storm water management, the workshop can improve future projects by awareness raising.

2.2.3. Case Houtmankade

The Houtmankade is a road on a quay in Amsterdam. The case Houtmankade focuses on the district north-west of the Houtmankade, the Spaarndammerbuurt, located in district Amsterdam West. There is only surface water at the east-side of the area, so storm water cannot flow from the lower parts to this. Besides that, the area is located low relative to the surroundings and dykes around. The situation after a rainfall event of 100 mm in an hour is presented in Figure 9. Together with planned construction works, flooding measures can be taken in the coming years. Construction works on the Houtmankade will start at the end of 2014. The road will be renewed, both the foundation and the surface. At the same time the road will be redesigned (Gemeente Amsterdam, 2013). A new road design has already been made, but some adaptations can still be made. The design of the Houtmankade might influence the flooding in the area.

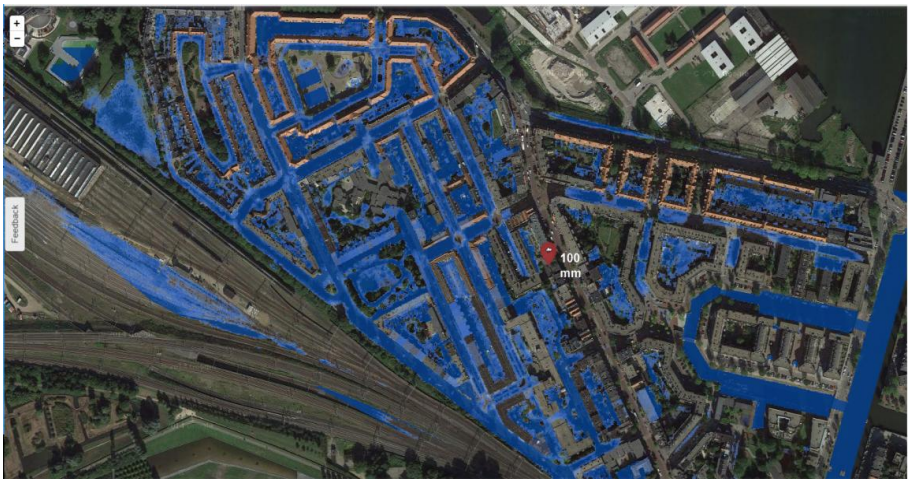


Figure 9: Houtmankade (right) and Spaarndammerbuurt after a rainfall event of 100 mm in 1 hour

2.3. Measurement method decision quality

Drawing conclusions about the improvement of decision quality by a model requires a comparison between two situations. The difference between the two situations identifies the possible improvement or deterioration. The difference will be measured in a workshop. A quantification of elements of decision quality is necessary for measurement.

2.3.1. Decision quality from literature

The terms better decision, better decision quality, decision, decision-making and decision-making process are not used consistently in literature. For this report, a better decision is seen as a decision of higher quality.

The literature describes many different definitions (or measurement methods) of decision quality. Decision quality is defined as the opinion of the decision-makers about their satisfaction with the final decision (Wilson & Arvai, 2006). Decision quality as both the quality of analysis and the commitment to action is used by many authors (Howard, 1988; Mcnamee & Celona, 2008). Most authors make a distinction between six elements of decision quality and some authors divide these further in sub-elements. The six main elements (see Figure 10) are similar in different studies, but the sub elements differ (Howard, 1988, 2007; Keisler, 2011; Matheson & Matheson, 1998; Mcnamee & Celona, 2008). The following framework combines the authors' sub elements:

- Decision framing
    - Clarity of the purpose
    - Definability of the scope
    - Consciousness of perspectives
- Alternatives
    - Creativity and diversity of alternatives
    - Level of detail of alternatives
    - Achievability of alternatives
    - Coherence of alternatives
- Information
    - Availability of information
    - Clarity of information
    - Correctness and explicitness of information
    - Awareness of uncertainty of information
- Values, clearness of preferences of values
- Logic
    - Logic of reasoning
    - Understanding of consequences of alternatives
- Commitment to action

Figure 10: Decision quality framework (Matheson & Matheson, 1998)

Another research field were decision quality is used is recommendation agent research (internet search help). The goal of this is to satisfy consumers by helping them getting better decision suggestions. The relationship and measure method of decision quality measures can lead to different strategies for recommendation agents (Aksoy et al., 2011). Aksoy et al. (2011) do not use the division in the six elements of decision quality, but uses an extensive list of decision quality measures that are not all applicable to water management models. An example of this is Preference-Dependent Measures, a measure how well the agent knows what the consumer's preferences are. The most important difference between decision-making of recommendation

agents and decision-making in storm water projects is the decision maker and the consumer role. The recommendation agent is the decision maker, and the decision is made for the consumer. The decision maker in a storm water project is the consumer, the model contributes to the decision-making process, but is not making the decision.

Hazelrigg (2003) compares different methods for design selection (as matrixes and six sigma) by identifying favorable properties of the methods. He uses partially the same criteria for decision quality but does not divide them in six main issues. The favorable properties focus on the output of the tools and are not applicable for this research because the 3Di system does not automatically give a 'best' option.

Much research about decision quality is done for health care, this is a slightly different view on decision quality because it is about the preferences of the client. Decision quality is here defined as 'The consistency of the individual's decision with their values, satisfaction with decision, participation in decision-making and patient-clinician communication' (Shared Decision Making Programme, 2012). The only input for the decision quality is the opinion of the patient. Elements of decision quality in health care are for example the ability of communication of questions, concerns and preferences and the provision of information (Fraenkel et al., 2011).

Decision-making process quality is also assessed in a military sense making process. Military sense making are all the cognitive and social processes that are involved in military command and control. Research of Jensen (2007) uses a workshop to identify the quality of the process. He measured the process quality by observation of a team's planning session. Military experts rated the plan quality using predefined criteria. Remarkable was that the plan quality results of the workshop were not different from the process quality result, so the same result was obtained for measuring process quality as plan quality (Jensen, 2007).

2.3.2. Conceptualization decision quality elements

This research incorporates the decision process without costs. Besides that, not all decision quality elements as described before are tested. Only the elements that can be affected by models are used, what makes the research easier and less extensive. The selection is made by analyzing which elements are affected by other models (the models described in section 1.4.3), Appendix A describes the argumentation for the choice. The results of this analysis is that the elements clarity of the purpose, definability of the scope, values and logic of reasoning are excluded from the research.

An overview of interpretation and measurement methods discussed in literature is given in this section for the used decision quality elements. Some decision quality measuring methods from recommendation agents from Aksoy et al. (2011) (see the previous section) are used in this study, the field of research is very different, but measuring methods can be similar. The same concerns military sense making and studies in health care.

Decision framing - The consciousness of perspectives

Framing refers to the understanding what has to be decided and why (Keisler, 2011). The consciousness of perspectives refers to the perspective of all decision makers together, do the decision makers see the full set of data and do they appreciate the issues and concerns of the other decision makers? (Mcnamee & Celona, 2008). Davern et al. (2008) state that the decision quality is higher when all relevant issues are taken into account. If, for example, the inhabitants of the area are not taken into account in the decision, the decision quality will probably be lower.

The input information of a model can change the consciousness of the perspective because someone's perspective depends on the received information. More visual information can lead to an increased perceptual process, decision makers can than explore the information better (Speier,

2006). In military sense making theory, a full treatment of all issues is also an important criterion for process quality. The concerned issues were compared in the study with the full list of issues determined beforehand (Jensen, 2007). This is not possible in this study, because the full list of issues is unknown beforehand.

Alternatives

In a decision-making process, the set of alternatives is defined during the preparation of the workshops. During the workshops alternatives can be changed when an interactive model (as the 3Di system) is used, the effects of the new alternative can be directly included. This element is not affected by other models (as the D-PHASE program), because alternatives cannot easily be changed during the workshops. Alternatives can be influenced by the functionalities of a model; if something is not possible in a model it can also not be part of the alternative (Hazelrigg, 2003).

Alternatives – Creativity and diversity of alternatives

The quality of the alternatives limits the decision quality; the decision process cannot be of high quality if some solutions are not considered. Mcnamee & Celona (2008) define the creativeness of alternatives as how much they differ from the normal situation. The alternatives should also differ enough between themselves and should include the total range of possible solutions (Mcnamee & Celona, 2008).

Alternatives – Level of detail of alternatives

Mcnamee & Celona (2008) define the level of detail of an alternative as if all details are included in the description of the alternative. The highest score is obtained if the alternative can be implemented directly, without further research.

Alternatives – Coherence of alternatives

The final decision of a decision-making process consists often of different smaller solutions. The coherence of an alternative is described by Mcnamee & Celona (2008) as if the elements of the alternative are a good combination. Leskens et al. (2013) state that alternatives may become less coherent when an interactive water simulation model as 3Di is used, because the process becomes a trial-and-error process. A strategy will lead to a higher chance of implementation. In the urban stormwater management program SWITCH, executed in several cities, a coherent and integrated approach is one of the goals for the future (Ellis et al., 2009; Jefferies & Duffy, 2011).

Information

The use of a model in the decision process will affect the amount of available data because the data is available through a model. The model determines therefore the availability of data. Information is the data supplied by the model or other ways of input (as handouts).

Information – Availability of information

Some studies state that more information results in higher quality, while other state that too much information decreases the quality. Hazelrigg (2003) states that better information for the decision always leads to better decision-making (what will not lead necessarily to a better decision). But others state that if data is not appropriate selected, many time has to be spend on analyzing inappropriate available data or searching for necessary data (Mcnamee & Celona, 2008). Speier (2006) concluded that a high amount of information usually increases the complexity of a task or decision, what can limit the accuracy of the decision. The availability of information is defined as the degree in which specific values are included in the data collection (Ge & Helfert, 2006).

Hwang & Lin (1999) argue that information load has much effect on decision quality, the decision quality decreases when the diversity or repetitiveness of the data set increases. Hwang & Lin (1999) also describe contradictory findings of other authors. These authors state that the information diversity only affects the decision time negatively, and not the decision quality. Information load

does not change decision quality. Hwang & Lin (1999) describe that the relation between information load and information processing is an inverted U curve, with less information less information is processed, with average information much information is processed and with much information again less information is processed. The information processing is seen as positively related to decision quality, so the relation between decision quality and decision load is also an U curve (Hwang & Lin, 1999).

Information – Clarity of information

More clarity of information and thereby understanding of the data will lead to a higher decision quality. To obtain a higher decision quality, the right presentation of information is needed and the representation should match the problem or task to perform (Speier, 2006). The information should be structured so everything can be understood and can be found easily. Arciniegas et al. (2013) define the clarity of information as the ability of users to understand the information. The design or the used models are not inevitably related to this.

The clarity of the information is mostly measured in other research by interviews and amount of use of the tool. Janssen and Uran (2003) measured the clarity of information with interviews, they compare the use of a map, graphs, tables and text. Subjects of the interviews were the preferred visualization of data and communication, as level of detail and difficulty. Janssen and Uran (2003) conclude that maps are the most preferred type of information presentation, but also other types of presentation should be available for those who are not willing to use maps. For the analysis of a negotiation support tool in the Netherlands, workshops were held, after each workshop questionnaires were completed about the understanding and the information involved (Goosen et al., 2007). The clarity of information is measured in one study by the intensity of tool use, the time using the tool, the group strategy and the performance conflict (Arciniegas et al., 2013). Sidlar & Rinner (2009) did an experiment in which the degree of success of a tool was calculated as the utility ratio, the actual use of the tool divided by the potential use. Arciniegas et al. (2013) use the degree of consensus or the match between user needs and the tool as method. They state that the usefulness can be measured by the group multi-criteria analysis and a test of the subjects understanding (Arciniegas et al., 2013).

Information – Correctness and explicitness of information

Mcnamee & Celona (2008) use the element correctness and explicitness of information. The quality score is high when the information is correct and detailed, low when vague adjectives are given. They include the reliability of the source in this element. Correctness and explicitness is by some authors defined as the only aspects of information quality. Ge & Helfert (2006) measure the information quality by its accuracy and state that this information quality is the key determinant of decision quality. Raghunathan (1999) supports this view partly, he measured the information quality as well only by accuracy, but recognizes that information quality is multi-dimensional.

Information – Awareness of uncertainty of information

Knowing how well you know something is very important, this is especially the case for expectations about future events (Mcnamee & Celona, 2008). For example, climate change projects are depended of the future and uncertainties are therefore very important. If uncertainty is ignored, risk-full decisions can be made that lead to uncertain results. Decision makers often believe that the quality of the data is high while it is not (Ge & Helfert, 2006). Uncertainties should be included in decision support tools to be effective for flood management (Akter & Simonovic, 2005). A deterministic model (where uncertainty is not taken into account) is only valid as approximation, conditions for uncertainty and risk should incorporated (Hazelrigg, 2003). Only ‘near sighted’ decisions might be made because opportunities and threats are ignored (Mcnamee & Celona, 2008). Ramos et al. (2013) adds that more uncertainty information results in more optimal decisions and more coherence between individual decision-makers’ decisions. This results as well in a lower diversity in decisions.

Logic

The logic of the decision is split in two parts following the framework of Mcnamee & Celona (2008). One part is the logic of the reasoning, what decision is made and why? The second part is the understanding of consequences of alternatives, what consequences are assigned to the alternatives and why? Using a model can affect the logic of the decision because new insights can be obtained from this model.

Logic – Logic of reasoning

Keisler (2011) defines the element logic as a combination of information, values and alternatives consistent with the preferences of the decision makers. Hazelrigg (2003) states that a clear reasoning can only be obtained when it is not contradicting itself and is using the maximum of available information. The decision should be consistent with the given data, alternatives and preferences. Decision makers are using often devices as decision trees to ensure clear reasoning (Keisler, 2011). Mcnamee & Celona (2008) measure a clear reasoning by whether it can be explained to an intelligent outsider. The reasoning should be possible to understand by someone that has not made the decision. Mcnamee & Celona (2008) use intuition as well as criterion for reasoning, the score for clearly reasoning is lowest when each decision maker only relies on his intuition.

Logic – Understanding of consequences of alternatives

The reasoning can be clear even when the consequences of alternatives are not fully known. In that case the decision is not optimal because effects can be ignored (Mcnamee & Celona, 2008). The consequences of alternatives have to be logically included in the decision. The value of alternatives for each decision criterion should be known to make a good decision (Mcnamee & Celona, 2008). However, this is only obligatory when a Multiple Criteria Analysis is used.

Commitment to action or implementation

Mcnamee & Celona (2008) state that the commitment to action or implementation mainly depends on the enthusiasm of the stakeholders, are they motivated? Motivation follows from involvement and insight in the total process according to them. Authors use different criterion to measure enthusiasm or motivation. Aksoy et al. (2011) use the 'choice liking', the interest in the choice. Jensen (2007) links the agreement of the decision makers with the decision to commitment. Yates, Veinott & Patalano (2003) use satisfaction as a criterion. Different methods are used in other studies to measure the enthusiasm and agreement. Mcnamee & Celona (2008) measure the degree of understanding of all decision aspects by the decision makers and their involvement in the decision. Others measure the satisfaction of decision makers with the final decision (Aksoy et al., 2011; Yates et al., 2003). Jensen (2007) uses the degree of agreement with the decision by the individual decision makers, is the decision seen as the best possible option? Jensen (2007) uses as well a value for how often decision makers express their disagreement during the process. Consensus is unanimous agreement of decision-makers in a process, this is not fully possible in a decision-making process, but can be partly obtained (Boroushaki & Malczewski, 2010). Many authors use quantifiable values as measurement method for consensus. Boroushaki & Malczewski (2010) use scores of a Multiple Criteria Analysis gathered during a workshop to measure the degree of consensus. They compare the individual scores for the solutions with the group scores. The MCA was individually so the weights for criteria were assessed individually too. Bender & Simonovic (1997) use almost the same method, they include values as the highest discrepancy and pair wise coincidence.

2.3.3. Operationalization decision quality elements

Objective information cannot be obtained for all elements. An objective measurement can therefore only be done for some elements, most elements can just be measured subjectively. Several authors performed studies about decision quality similar to this research. They use mostly quantifiable values, which are difficult to set up for the cases in this study. For example, Ge &

Helfert (2006) use relations for the accuracy and availability of information. They know the total number of data items possible and can draw conclusions from this. The measurement methods for the decision quality elements are given in the following sections.

Decision framing - The consciousness of perspectives

The consciousness of the participant's perspective is measured by the number of aspects they involve in the decision-making. In addition, it is checked if these aspects are equal between the decision makers. If participants mention much of the same aspects, the quality is higher. Aspects are defined as subjects that should be incorporated in the decision, as inhabitants or traffic. The aspects are collected by asking the participants to list them. Participant used different terms for equal aspects, so these aspects are categorized. The used categories and aspects can be found in Appendix F.2. The total collection of relevant aspects is not known; it is therefore difficult to compare different cases. The comparison with the reference situation is made by asking the participants if they have involved more issues than in their normal situation.

Alternatives – Creativity and diversity of alternatives

Creativeness and difference of the alternatives are rated as one element. Creativeness is how inventive or original the alternatives are. Significantly different is how much the alternatives vary between each other. This element is measured by the number of alternatives made up during the workshops, the differences between them and the differences with the given alternatives. Alternatives are seen as more different if they focus on different locations and different kind of solutions (as storage versus draining). The creativeness is determined by the difference with the given alternatives. The comparison-score is obtained by asking if participants considered more alternatives by using 3Di instead of their reference situation. It is expected that the creativity and diversity of alternatives is higher if more alternatives are considered.

Alternatives – Level of detail of alternatives

A value for this element is assigned by how much detail is added to the alternatives during the workshops. Adding more detail means a higher quality. This is measured by asking the participants in the questionnaire how much detail they have added to the alternatives. As comparison participants are asked if they could elaborate alternatives more detailed with 3Di than in their reference situation.

Alternatives – Coherence of alternatives

The coherence of alternatives is measured by presence or absence of strategy between the sub-solutions. The sub-solutions are parts of the final solutions that are tried during the workshops. Participants were asked if they see a strategy between the sub-solutions. Besides that, the final solutions are analyzed, these can be found in appendix F.2. The quality is higher if the different measures in the final solution are cohesive. Sub-solutions are cohesive if the same range of solutions is used, for example if green roofs are used at different locations or if different sub-solutions strengthen each other. An alternative is non-cohesive if it contains different methods, as green roofs, a threshold and permeable streets. Besides this measurement method, for comparison with the reference situation, participants are asked if it is easier to apply a strategy with 3Di.

Information – Availability of information

This element has a high quality score when all desired data for the decision are available and no unnecessary information is presented. The element is measured by the participants' opinions about the availability of data and the data they miss. Presenting all wished data is not possible, so this data should be excluded from the question. A comment about this exclusion is therefore incorporated in the question. The measurement for comparison between 3Di and the reference situation is done by asking the participant's opinion about the improvement in data availability and missing data.

Information – Clarity of information

The clarity of the model information is measured by the time necessary and difficulty to find the right information. The time needed reflects the usability of the model, the time will be short with a good structure. Besides that, clarity will lead to an easy to use model; users know where they have to find information. These two aspects are measured in the questionnaire by asking participants about their opinion of the time and difficulty. This is done for both the quality of 3Di and the comparison with the reference situation.

Information – Correctness and explicitness of information

The quality of the data is defined as the correctness and explicitness of the data. These aspects make up one sub element because correctness of data is meaningless if the data is not detailed. The explicitness of the information will be obtained by the opinion of the decision makers. How do they perceive the explicitness of the information, it is detailed enough? This is different from the availability of information because this is about the amount of data (categories and location). The correctness is measured by the opinion of the participants about the correctness. It could have been done objectively but that would have been very time-consuming. It is not the objective of this research to determine the accuracy and correctness of the information or models. It is stated by the producers that 3Di is simulating the real world quite correctly (Consortium 3Di Waterbeheer, 2014). This element is measured in the questionnaire by asking the participants about the correctness of and details in the information.

Information – Awareness of uncertainty of information

The awareness of uncertainty of information is measured by the perception participants have of the uncertainty of the model. The quality of 3Di for this criterion is only determined by participants' opinion about the veracity of 3Di. This should be compared with the real veracity, unfortunately this is not possible. This element is therefore not presenting a score for the awareness of uncertainty. The comparison-score is determined by comparing the results of two questionnaire questions. The first question is about their knowledge of the veracity of the reference situation. The other question is about their knowledge of veracity of 3Di, by asking how well they felt informed about this. The score is high if the first question got a lower rate than the second.

The information given during the workshops is influencing the awareness of uncertainty. The uncertainty was therefore not explained in detail during the presentation about 3Di. The accuracy of the calculation method of 3Di was mentioned and the inclusion of different modules (as ground water and sewerage). The 3Di system is not finished what can lead to additional critique about the correctness. The lack of the sewage module was therefore shortly mentioned during the presentation at the start of the workshops. The lack of the sewage model is not expected to influence the model results a lot, because an additional interception layer simulated sewage in the model. This was also explained during the workshops, so the opinion of the participants will be affected only a little.

Logic – Logic of reasoning

The element logic is defined as the logic in choosing the final decision. The final decision is made per group in the workshops by choosing best option out of the alternatives. The final decision is implemented in 3Di during the workshops. The rate of clear reasoning is measured by the understanding why the final decision is chosen and if much intuitivity is used. If the understanding is higher, the clearness is higher. However, more use of intuitivity leads to a lower clearness. The questionnaire contains four questions about this element, two for the quality of 3Di and two for the comparison with the reference situation. For both situations, one question about the intuitivity and one about the understanding of the final decision was asked.

Logic – Understanding of consequences of alternatives

The logic in a decision is higher if alternatives can better be compared, so if the consequences of the alternatives are better known. This can be measured objectively when a Multiple Criteria Analysis (MCA) is used, due to the quantitative scoring. Nevertheless, no MCA is used in the reference situation, so is not used in the workshops. The opinions about the understanding of the consequences are thus asked in the questionnaire. The consequences are divided in water hindrance and other consequences, because it is expected that only the knowledge of consequences for water would change by 3Di.

Commitment to action or implementation

The commitment is measured by the satisfaction with the final decision and the degree of agreement between the decision makers. Participants were asked about their satisfaction with the final decision in the questionnaire. Besides that, they were asked about the alternative they would have chosen as final decision. A comparison can be made between the individual's best solution and the group's best solution to determine the degree of agreement.

2.4. Interviews

Interviews are held for three reasons. First, the limited written information about urban storm water management projects and the decision-making in these projects. Secondly, additional knowledge about the cases can improve the quality of the workshops and questionnaire. Thirdly, the validity of the study will be higher because information can be checked at different sources.

In total, nine interviews are held, summaries of the interviews can be found in Appendix B. Besides the interviews, several discussions and meetings with co-organizing people of the workshops from Waternet have been held. One interview was held about the use of 3Di in Watergraafsmeer. One interview was about the general use of models for urban water problems (specified on Apeldoorn) and WOLK. Three interviews with participants of other water projects that are not focusing on water management but on the integration of water management were held, these projects are executed in Rotterdam (Waterplein Rotterdam), Zwolle (klimaatdijk) and Purmerend. Three interviews were held as preparation for the Rivierenbuurt workshop, one with an asset management strategy developer from Waternet, one with a project manager Rijnstraat of the district council and one with the public space manager of the Rivierenbuurt of the district council. In preparation of the Houtmankade workshop an interview was held with a project manager of the district council Amsterdam West.

The interviews were semi-structured. The interviewer used a standard list with topics and questions of interest to check if all subjects were discussed. Only applicable questions were discussed during the interview. For instance, if the interviewee was not using a water simulation model, questions about this could be skipped. Sound recording of the interviews was done to improve the correctness of the interview report. The interviewees checked the report afterwards on correctness and gave approval of publication in the report.

During the interviews one representative project was chosen to discuss, as the Waterplein en Klimaatdijk. The alternatives, model use and decision-making process of the projects were the main subjects of these interviews. The interviews as workshop preparation were focused on the workshop areas and the problems there. Main topics were the decision-making process, use of models and the involved parties.

2.5. Workshops

The main results of the study are obtained with two workshops. With the workshop results the decision quality of the 3Di system, the decision quality in comparison with the participants' reference situation and possible improvement of the decision quality are identified. The workshop results are a questionnaire, video image of a discussion and case answers of the workshop groups. One workshop for each case is held. This section describes first the explanation of the choices made for the workshop. After that, the workshop schedule is described. Last, the content and interpretation of the questionnaire are described.

2.5.1. Points of attention for the workshop setup

Additional information is used to ensure a good quality workshop; the results are more reliable if the workshops will went smooth. Some requirements and wishes for the 3Di model and the workshops were pointed out in literature, during interviews and during other meetings. Other aspects of improvement became clear during the test workshop held before the workshops.

The test workshop was executed on May 21, 2014, using the model Rivierenbuurt. Two employees and four interns of Nelen & Schuurmans participated. They had no prior knowledge about the area and the problems, so an in-depth discussion was not possible. However, the case was studied and ideas for the real workshops were gained. The participants found the setup of the test workshop somewhat vague, this was due to the absence of an explicit problem definition in the Rivierenbuurt. A solution for the problem was therefore not obtained. The problem definition is therefore made more explicit to get a more effective workshop.

In addition, it became clear during the test workshop that an extensive explanation of the 3Di system is necessary. The article of Leskens et al. (2013) supports this, it states that model output should also be understandable for non-water specialists. A detailed introduction of the 3Di system is therefore included in the workshops, before handing out the case. For additional understanding, some examples of the implementation of alternatives in 3Di are shown. Participants of the test workshop had many questions about the assumptions of the model and thereby the reliability. Examples of questions were which data were used for the model and what the input values were. This is possibly caused by the high interest of the participants in the 3Di system and will not certainly be similar in the real workshops. However, additional information supply for the participants will reduce the number, and thereby, time of questions. The participants are thus provided with maps (as for elevation and land use) and a list of assumptions. Previous interviews within another study revealed that technical reliability is very important for a model (Leskens et al., 2013, p. 5). Technical reliability is included thus by using a detailed 3Di model in the workshops, although this cost much time to make (see the previous section for more details about the 3Di model).

The effectiveness of alternatives should be possible to assess in the time set for the workshops (Leskens et al., 2013). The case is therefore kept simple. However, the possibility of adaptation of the 3Di system is an important advantage according to the interview with Anne Leskens. Time for adaptation of the model is therefore integrated in the workshops. Possible solutions were not yet prepared during the test workshop, so the participants did not know what sort of solutions they could try. When the real workshops are done, participants know more about the area and will probably come up with solutions themselves. Nevertheless, some solution suggestions will contribute to the effectiveness of the workshops.

Participants of the attended workshop 'Rivierenbuurt Rainproof maken' at May 8, 2014 pointed out that it is nowadays unclear how much a solution can reduce the water problem. It would be very useful if these details can be obtained with 3Di, so this should be possible during the workshops. The reduction of the water problem is therefore quantified during the workshops by looking at the

water heights at certain locations in the 3Di system. The same demand for details became clear during a discussion of the working group the Nieuwe Wibaut on April 11, 2014. Attendees asked for example what would change in the flooding when paved area (e.g. 1 m^2) is changed in unpaved area. They also pointed out that an elevation map of the area would be helpful to see where the water comes from. Thomas Staverman wishes even to have an overview of the cesspits in the model. In this way, the flow over the street can be simulated in detail. Unfortunately this is not yet possible with the 3Di system. However, Jeroen Kluck states in the interview that the municipality does not always want more information. The current knowledge is sometimes enough to make decisions, because there are many other uncertainties, for examples in rainfall amount and location. This doubt is therefore included in the questionnaire.

2.5.2. Workshop schedule

The program of the workshops was as follows:

1. **Rainproof presentation** by Eljakim Koopman (member of Rainproof Amsterdam) and Daniël Goedbloed for the workshop Houtmankade (team leader of Rainproof Amsterdam). They presented the motivation of the Rainproof program and the workshop itself. Besides that Daniël Goedbloed gave some information about the 3Di system.

2. **3Di presentation** by Floor Speet. The functions and possibilities of 3Di were explained. In addition, a demo of 3Di was shown on a beamer screen. As a result of the presentations, participants asked questions about the integration of the sewer system and the reliability of the 3Di system.

3. **Introduction of the case** by Floor Speet, the case location was inspected with 3Di and the problem was explained. The participants of the workshops were given handouts in addition to the use of 3Di. The handouts can be found in Appendix C. The same information as can be found in 3Di was in this way better accessible. The handouts were a digital elevation map of the area, maps of prepared alternatives (as locations of green roofs and permeable areas), a satellite and street map on A3 and a screenshot of the flooding result after a 100 mm rain of 1 hour. The rainfall quantity of 100 mm was fixed to reduce the number of discussion points in the groups. Besides that, an overview of the case, including description of alternatives, was given.

4. **Discussion about the case in groups**, three groups for the Rivierenbuurt workshop and four groups for the Houtmankade workshop. The assignment was to find several alternatives for the problem and choose their best one to present in the next step. No criteria for the best solution were given, so groups chose mostly a somehow realistic (qua price) solution that was expected to solve a large part of the water problem. Leading of the groups was done by people from Waternet and Rainproof that helped organizing the workshops (see the list below for the exact persons). Groups could choose predefined alternatives or come with something new.

5. **Presentation of the best alternative per group in 3Di.** Each group had chosen an alternative to check with 3Di. Floor Speet was operating the 3Di system on a touch table, while the group members stood around the table and gave input for the model. The effects of the alternatives were tested by running the model with and without the alternative for a rainfall event of 100 mm in an hour. The differences could be identified by making a cross-section and check the water height on certain points. Ground use could not be adapted in the model, but some scenarios were made beforehand for alternatives were this was necessary. Other groups were watching while the one group was using the model.

6. A **summary** of the possible solutions and effects of these was given by showing some results on the beamer screen. In addition, some last questions were answered.

7. The **questionnaire** was handed out, and all participants completed it.

Different people did the moderation for both workshops. The presence of two extra experts resulted in a slightly better answering of the asked questions by the participants. However, this was leveled partly by the increased knowledge of Floor Speet during the second workshop (Houtmankade). The presence of the head of Amsterdam Rainproof led to a more detailed and critical presentation about 3Di. The workshop Rivierenbuurt was led by:

- Floor Speet, as explainer of the case and expert of 3Di
- Eljakim Koopman, member of Rainproof and Waternet, explaining the reason for the workshop
- Anne Leskens and Jorik Chen, from Nelen & Schuurmans, as experts in 3Di, answering complex questions of the participants
- Wilko Koning, program manager Waternet, co-organizer of the workshop and sender of the invitations, as honorary chairman

Workshop Houtmankade was led by:

- Floor Speet, as explainer of the case and expert of 3Di
- Eljakim Koopman, member of Rainproof and senior policy advisor Waternet, explaining the reason for the workshop
- Daniël Goedbloed, head of Amsterdam Rainproof, explaining the reason for the workshop and Amsterdam Rainproof
- Erik de Bruijne, program manager Waternet, co-organizer of the workshop and sender of the invitations, as honorary chairman

2.5.3. Questionnaire

The questionnaire contained three types of questions, general questions about the participants' specifications, questions about their opinion on 3Di and comparison-questions of 3Di with their reference situation. The questionnaire can be found in Appendix E.

Measurement method questionnaire

The aim of the questionnaire is to obtain the opinion of them about the model that is used. Besides that, the questionnaire has to show the difference between using and not using the 3Di system. The opinion of participants about a certain subject can be measured with attitude measurement. Attitude measurement is thus used in the questionnaire. It is the measurement of someone's or a group's attitude. Attitude focuses on a specific entity or object, not to all objects and situations related. It is the tendency to like or dislike the object or situation (Krosnick et al., 2005). Some questions in the questionnaire are not part of the attitude measurement because they are about facts, for example if participants use a model normally. Besides questions about their opinion of the used model, comparison questions between 3Di and their reference situation are added. It is not possible to ask the same questions before the use of 3Di and after, because many participants are not using a model in their normal work. Therefore, participants are asked if 3Di changes their experience, for example by asking if they have more information about the problem. The questionnaire can be found in Appendix C.

A scale form is used to measure the attitude of the participants in this study. A scale form is easy to use for analytical studies (Akter & Simonovic, 2005). Akter & Simonovic (2005) test different input forms for attitude measurement, scale form, linguistic form and conditional form. The applicability of a linguistic method for a "real flood management situation" is higher according to the authors

(Akter & Simonovic, 2005). More and relevant information can be obtained from the participants, because it can be used in an informal setting. But the differences between the scale form and linguistic form were low (Akter & Simonovic, 2005). A scale form is thus used to ensure an easier interpretation of the questionnaire.

Well-known attitude measurement scales are the equal-appearing intervals method of Thurstone, the Likert-scale of summated ratings, the semantic differential method of Osgood, Suci and Tannebaum, the cumulative scale of Guttman and the reasoned method of Fishbein and Ajzen (Krosnick et al., 2005; Pligt & Blankers, 2013). The Likert-scale is most used due to the easiness of set-up and interpretation (Pligt & Blankers, 2013). A disadvantage of the use of a Likert-scale is that the distances between the answer options are not equal. The Likert-scale will be used as answering option for most questions. The Likert-scale gives reliable results and is easy to interpret.

A 7-point Likert scale with names for each point and a 'no opinion' option is used mostly in the questionnaire. Participant's understanding of scales above a 7-point scale decreases fast by an increasing number of points. Besides that, Krosnick et al. (2005) state that a 7-point scale increases the easiness of filling out the questions. Leaving out a midpoint or a 'no opinion' option can lead to inaccurate measurements (Krosnick et al., 2005), so these are included. The response percentage for a question will reduce when a 'no opinion' option is included. But this will not reduce the accuracy of the result (Pligt & Blankers, 2013). Names will be assigned to each point because the understanding of the points increases when a name is assigned to the points (Krosnick et al., 2005). Vagias (2006) lists several Likert scales with description for every point. An example is "strongly disagree, disagree, somewhat disagree, neither agree or disagree, somewhat agree, strongly agree" to measure the level of agreement (Vagias, 2006). These names are used in the questionaire (translated to Dutch). This is done both for the questions about the 3Di quality and for the questions where a comparison is made. For the comparison questions the fourth option, neither agree or disagree, means that there is no difference with the reference situation.

Open questions are included in the questionnaire because some decision quality elements cannot be measured by attitude measurement questions. Besides that, some open questions are included to check the reliability of the closed questions. Closed questions can be distorted is they are not understood right (Krosnick et al., 2005).

Distortion in the results of the questionnaire is reduced as much as possible by paying attention to the formulation of the questions. Pligt & Blankers (2013) lists some of the most important issues for the formulation. Most questions have thus only one subject, more subjects would be confusing. Also clear terms are used and the term 'final decision' is explained at the form. The questions are held as simple as possible, inevitably, they are still quite long sometimes. Besides that, the questions should be objective, to ensure reliable answers.

Analysis of questionnaire results

Most questions in the questionnaire, the Likert-scale questions, can be interpreted directly from the answers. Other questions, as the number of aspects had to be analyzed to obtain a value for a criterion. The following answers are processed to obtain a value for a criterion:

- If participants answered that they are working sometimes with flooding, it is seen as a 'yes'. In this way, only 2 categories have to be distinguished.
- The number of aspects mentioned is sometimes corrected if participants give two aspects of the same category, as bicyclists and traffic. The mentioned aspects are sorted by category per case (Houtmankade and Rivierenbuurt separated), to obtain a value for overlapping of the aspects. This value is set as how much of the mentioned aspects are also mentioned by other participants.

2.6. 3Di system

The basic model of the 3Di system consists of combined information layers, as the AHN2 (actueel hoogtebestand Nederland), Basisregistratie Adressen en Gebouwen (BAG)) and TOP10 (topographic information) (Nelen & Schuurmans, 2014). Detailed layers with the infiltration, interception and resistance are made with this information. Only the interactive web viewer is used in this research to present the 3Di system. This is accessible via www.live.3Di.lizard.net.

The model is relative fast and detailed because the calculation cells are determined with the quadtree method; square cells are divided in smaller square cells if more details are useful at that location (Stelling, 2012). In this way, riverbanks are considered very detailed while plain areas that have the same characteristics are seen as one cell. Besides that, the model is quick because of the use of tables in the calculation. Calculations are already prepared in the tables and the model uses these tables to find the results for a specific situation. The surface flow is calculated with the ontinuity and momentum equations of Saint-Venant; each step the amount of water that flows to surrounding cells is calculated (Nelen & Schuurmans, 2013b).

A new 3Di model specific for the locations had to be built for the workshops, to get the best results, choices had to be made for this. An example is that with more detail the calculation time increases, so choices between detail and speed have to be made. Besides these choices, some possibilities of the 3Di system can left out without consequences for the results. Other possibilities can change the outcome of the calculation and therefore the outcome of the workshops. The choices are based on the principle that the 3Di model should represent the reality as much as reasonable. Besides that, the model has to stay user-friendly and suitable for the workshops. Appendix D gives a detailed description of the input parameters and choices for the 3Di models. This section describes the most important choices:

- The groundwater module was left out for both workshops, although it was possible to include. Model tests showed that exclusion or inclusion of groundwater is not changing the outcome of water on the street significantly. The model simulates only some hours in the workshops and in this period almost no changes occur in the groundwater level.

- The sewerage module was not included in both models, because this is still under development by the 3Di consortium.

- As replacement for the sewerage module, an interception layer of 7 mm is added to the total area. The interception layer simulated the filling up of the sewage because the first rain will drain to this interception layer. An amount of 7 mm is chosen because this is the design amount of the sewage in Amsterdam.

- The model boundaries of the Rivierenbuurt are the Amstel at two sides and other canals at the other sides. The model boundaries of the model Houtmankade are the Westerkanaal (along the Houtmankade), the railway embankment and the Spaarndammerdijk. No inflow or outflow is set on the boundaries.

- Canals or rivers can be simulated in 3Di with 1D-canals (instead of only dependent from the ground height). 1D-canals are not included in both models because the canals are only located at the boundaries of the areas. Not using 1D-canals will therefore not influence the results.

- The calculation grid size of the model is refined around the focus areas of the cases. For the case Rivierenbuurt this is the Rijnstraat and surrounding streets and green areas. For the case Houtmankade a smaller grid size is given to points of interest in the area, as the Houtmankade and the locations of possible measures.

- The water level in canals and waterways in Amsterdam is drained to -0,4 NAP according to Waternet. The initial water level in the model is therefore set at -0,4 NAP.

- No large construction works are done in both areas, so therefore no adaptations have to be made in the data layers (as the elevation map) to update the model to the current situation.

The version of 3Di of June 2014 was used, there was no difference between the version of the first and second workshop. The possibilities of the system during the workshops can best be explained by a screenshot of 3Di, see Figure 11. With the buttons below on the left (from left to right), a cross-section can be made, resulting in a graph as showed top left. The simulation can be paused or continued. A rainfall event can placed with the 'cloud' button, this rainfall event is simulated as a circle in which the amount of rainfall per hour can be chosen. A tap that gives a chosen number of point outflow in m^3/s. A pump, the opposite of the tap. The square with pencil is to change ground elevation level by clicking on the map. A ground level (against NAP) can be chosen or a difference in comparison with the current situation (plus or minus a certain distance). Bottom right the simulation time is shown. On the right a menu is given were values for rainfall intensity, ground elevation change and blue coloring of the water can be adapted. Top right (from left to right) different maps can be chosen (as satellite or street map), the DEM or grid can be shown, another model can be chosen, login and opening the menu.

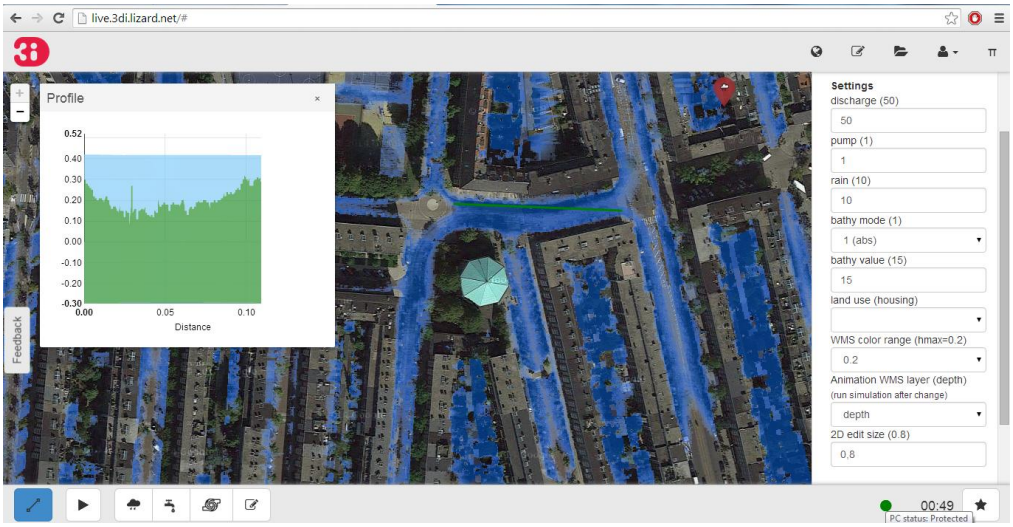


Figure 11: Screenshot of the 3Di live site with a model of the Rijnstraat, Amsterdam

3. Results

The results of the workshops, questionnaire, interviews and other information sources are described in this chapter. The current situation of decision-making is given in section 3.1. The results of the questionnaire are divided in two categories, the decision quality of 3Di itself (in section 3.2) and the comparison of the 3Di system with the reference situation (in section 3.3). Finally, the results are described in detail per decision quality element in section 3.4.

The main source for the results is the questionnaire; 31 participants have completed it. These participants are categorized by two characteristics, their reference situation (using or not using a model) and the case they participated in. This categorization gives additional information about the reliability and reasons for their answer. Sixteen participants completed the questionnaire for the Rivierenbuurt workshop, fifteen participants for the Houtmankade workshop. Only one of them had worked with 3Di before, seven of them are not working with water hindrance during their normal activities. Only eight participants use a model for water hindrance, as WOLK or Infoworks. Not many differences could be seen between the participants working with water problems normally and those who are not. No results categorized by this property are thus shown.

3.1. Current situation of decision-making

The current situation of decision-making should be known to make a good comparison with the new situation using 3Di. Information about the current situation of decision-making is compiled from the interviews and attended meetings during the study period. Attended meetings were a consultation with the group 'Nieuwe Wibaut' at April 11, 2014 and the workshop "Rivierenbuurt Rainproof maken" organized by Nieuwe Wibaut on May 8, 2014. Besides that, some information obtained during the workshops was used to determine the current situation of decision-making.

The results answers the first sub question of the study and gives necessary information for the execution of the workshops. These results helps to make the comparison of 3Di with the current situation. At least the current situation of decision-making should be known for this.

3.1.1. Description of the steps taken in the decision-making process

The decision-making process cannot exactly be described with a start and end-time. Before an actual decision is made, many steps have to be taken. An example is a decision on the direction of the alternatives according to the interview with a PhD student (see Appendix B.3). First, a decision about the sort of solution is made, after which more detailed alternatives are made. A new decision is needed to choose between these alternatives.

Some projects about decision-making for future extreme rainfall are not started from a problem, but from a chance or possibility. The project manager of the water square 'Benthemplein' stated that it was the idea to implement a water square from the beginning (see Appendix B.1). This was equally for the noise barrier in Zwolle, the project was originated by the possibility of integration instead of a current problem. A noise barrier and embankment could be combined to reduce future problems, see Appendix B.2 for a summary of the interview.

A water expert and lector stated that detailed alternatives are mostly not used in decision-making processes for extreme rainfall in cities. Mostly combinations of alternatives are used after which one of these is worked out in detail. A multi-criteria analysis is mostly not used due to a vague project goal and alternatives.

Decision-making about the design for an urban project is often done without direct communication, only communication via mail is used. The municipality, landowners, water boards and cable and pipe organizations react on the first design with a wish-trace (wenstracé). The wish-trace contains

preferred changes and information about construction time needed (e.g. for applying cables underground). An asset manager of Waternet involved in sewage explained this for a road reconstruction in Amsterdam. The district councils make a road design. This design is send to the other stakeholders of the construction works, as gas-, internet- and sewer companies, Waternet is one of these parties. These companies react with a wish-trace by mail. The interviewees from the district councils endorse this course of the decision-making (see Appendixes B.6, B.8 and B.9). The decision-making process is about the same in Purmerend (see Appendix B.5).

The municipality of Amsterdam is large so departments are sometimes physically far away from each other. An asset manager of Waternet states that this leads to decreased communication between different stakeholders. In smaller municipalities these departments are better connected, or are even integrated. When these departments are more closely connected, discussions between them are held automatically.

Water on the street is not very important in urban projects. Water hindrance on the streets is expected in the future, but stakeholders of such projects are often not aware of the importance. Waternet is in Amsterdam responsible for sewage until 7 mm rainfall per hour. Interviewees do not agree with the organization in charge of the excess rainfall during a heavier rainfall event than 7 mm per hour. Interviewees from Waternet state it is the responsibility of the city council. Interviewees from the district council are not aware whose responsibility it is. Some of them see initiation of a rainproof design as the responsibility of Waternet. The municipality of Amsterdam is responsible to provide (the 'zorgplicht') the discharging of ground water and rainwater from public space to the sewage (Baaren, 2010). 'Zorgplicht' means that they are approachable for problems with this. However, the existence of Waternet can cause problems with this responsibility. Waternet is performing the executive tasks of the water board and the municipality.

An important stake of decision-making in the discussed projects in Amsterdam is money. During the workshop of the Nieuwe Wibaut on May 8, 2014, the participants extensively discussed about money and budgets. The participants stated that a project could only be done with a Rainproof design if extra money is available. In addition, the year budget of the organization should allow it. The public space manager of the Rivierenbuurt supports this because organizations are not collaborating in a new project when they have no budget left. He suggests that this could be more effective if organizations would have a joint budget.

3.1.2. Model use in the decision-making process

Water simulation models were mostly not used in the projects of the interviewees. Water squares in Rotterdam are, according to the project manager, not dimensioned on a certain amount of storm water. The water square is implemented how it could best fit the other purposes. In addition, the sound barrier in Zwolle is built because of the possibility of integration a sound barrier and flood prevention. The height of the embankment was high for water prevention because the sound barrier has to be that height. A detailed model to predict water height was thus not used or needed.

According to the interviews, most people of the district council contributing to a new road design do not use models to predict the water discharge. Although, Waternet is using Infoworks and sometimes WOLK, models for sewerage and runoff. This can also be seen in the results of the questionnaire, only eight out of the 31 participants of the workshops were using a model in their normal work. Used models by the participants of the workshops are Infoworks, WOLK or other models. An asset manager of Waternet said he is only informed about the results of the models by other people and is not using them himself. The same asset manager of Waternet stated that a disadvantage of the currently used Infoworks is the focus on sewerage; street water flow is not integrated. Employees of the district council are using mostly experience or guidelines to make decisions about the water flow. Possibly colleagues of the interviewees use models, but do not use model thoroughly. Besides that, the district council is not always checking a design for water flow

because they do not have the responsibility. According to Jeroen Kluck, a model is not necessary to identify solutions for flooding by extreme rainfall, because the solutions are often obvious. In that case, a model is helpful to convince others about the need.

3.2. Decision quality of 3Di

The 3Di decision quality questions led to an overview of the opinion of the participants of the 3Di system alone. These opinions can point out the strong and weak points or points that can be improved. A full overview of the questionnaire and workshop results can be found in Appendix F. The differences between the participants that works with water normally and the participants that were not working with water normally are quite small. These differences are therefore not discussed in detail in this chapter, the detailed results can be found in the appendix.

Figure 12 presents the average score and spread of the decision quality elements and the rate for decision quality. The average score '4' means 'not positive, not negative'. Below '4' is negative, above is positive. The score for the element 'conscious' is relative, so should be '4' when all participant categories are included. From Figure 12 can be concluded that the availability of information and the clearness of reasoning are rated as relative weak elements. The coherence of alternatives and understanding of consequences of alternatives are seen as strong elements.

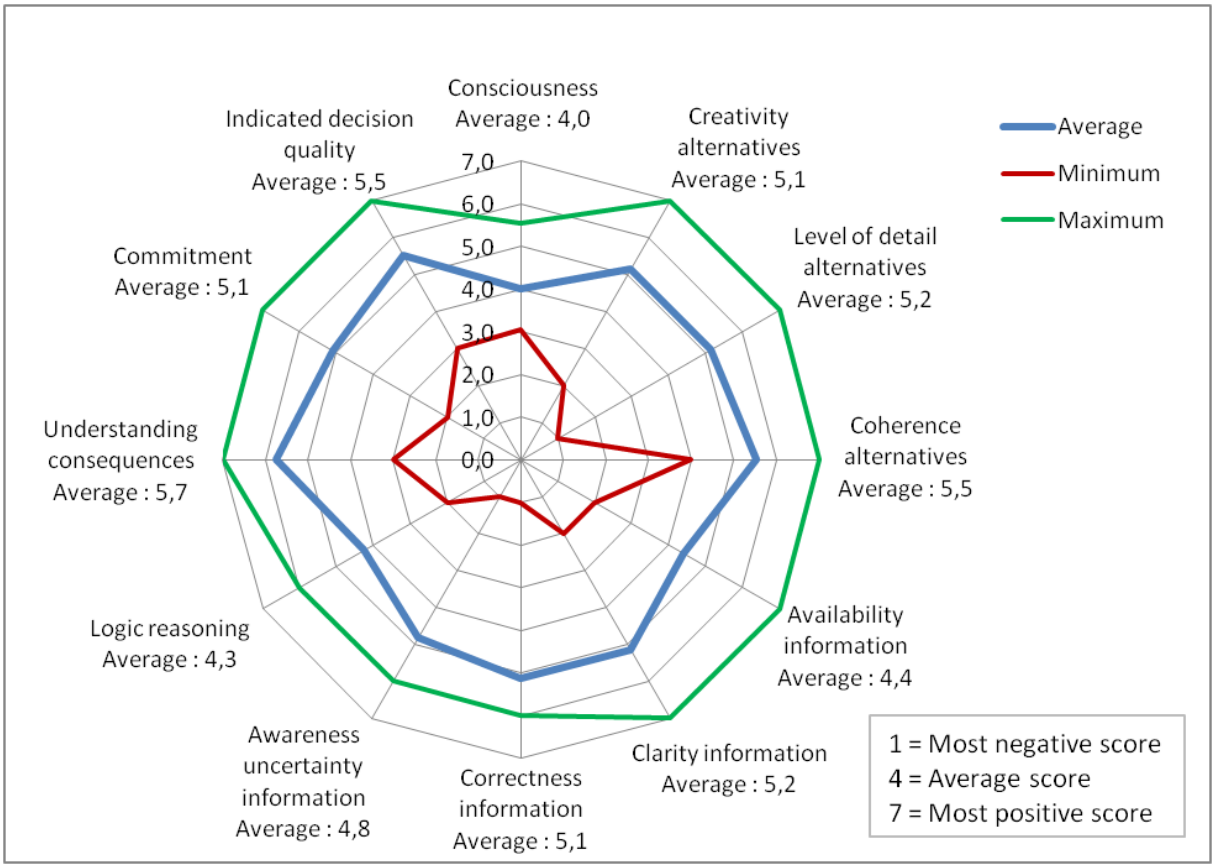


Figure 12: Average scores of both workshops of decision quality elements for the 3Di system

Figure 13 (at the next page) gives an overview of the scores sorted by participant category. The figure shows that the spread of answers is very high for the commitment of the final decision. The high score for Houtmankade/using a model is only of one participant, the other two chose 'non-applicable', the high score is therefore not reliable. This is equal for the element logic reasoning although this element has no striking value. All three participants from that specific group answered the other elements. Many participants did not answer the elements commitment and logic

reasoning, but this will affects the other groups not so much because of their larger size. The low score for logic reasoning is thus based on a small number of answers. Another striking point from Figure 13 is the difference between the groups using a model and not using a model of the Houtmankade workshop. These groups got the highest and lowest score for consciousness, level of detail of alternatives and indicated decision quality. The scores for the workshop Rivierenbuurt are located in between. Participants of the Houtmankade using a model are thus much more positive about these elements than participants not using a model in the workshop Houtmankade.

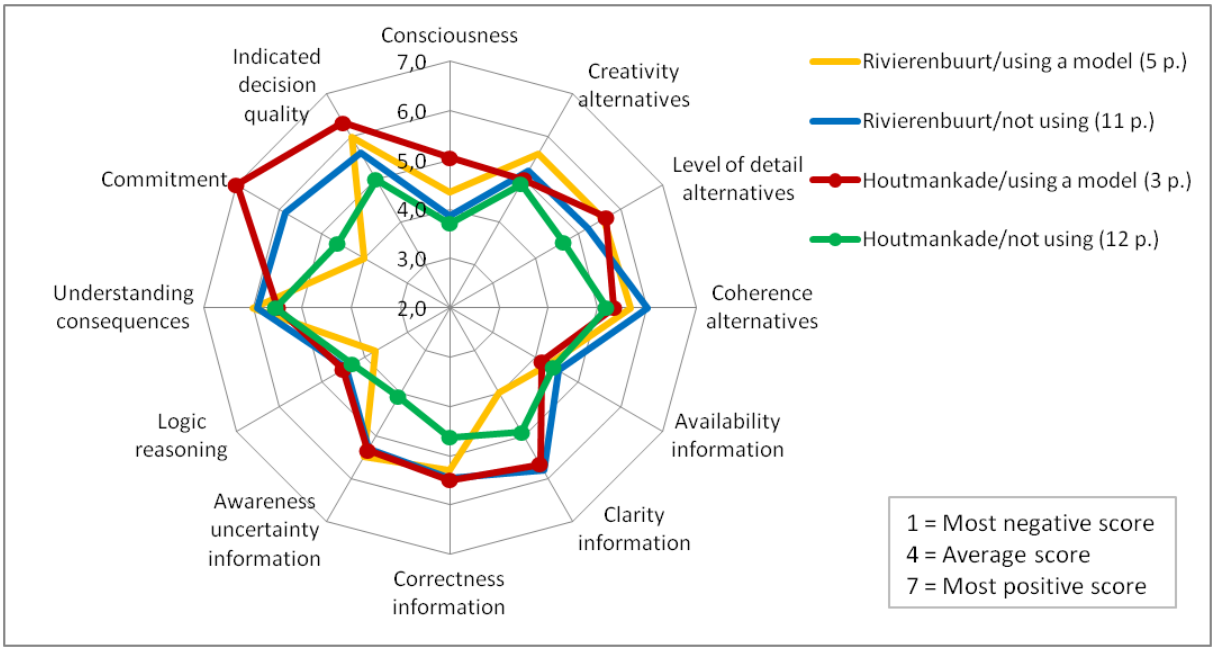


Figure 13: Average scores of decision quality elements for the 3Di system split up per workshop and reference situation

Participants from the Houtmankade workshop rated all aspects on average lower or equal than participants from the Rivierenbuurt, see Figure 14. Especially the correctness of the model was rated much lower, 4,3 against 5,4 for the Rivierenbuurt.

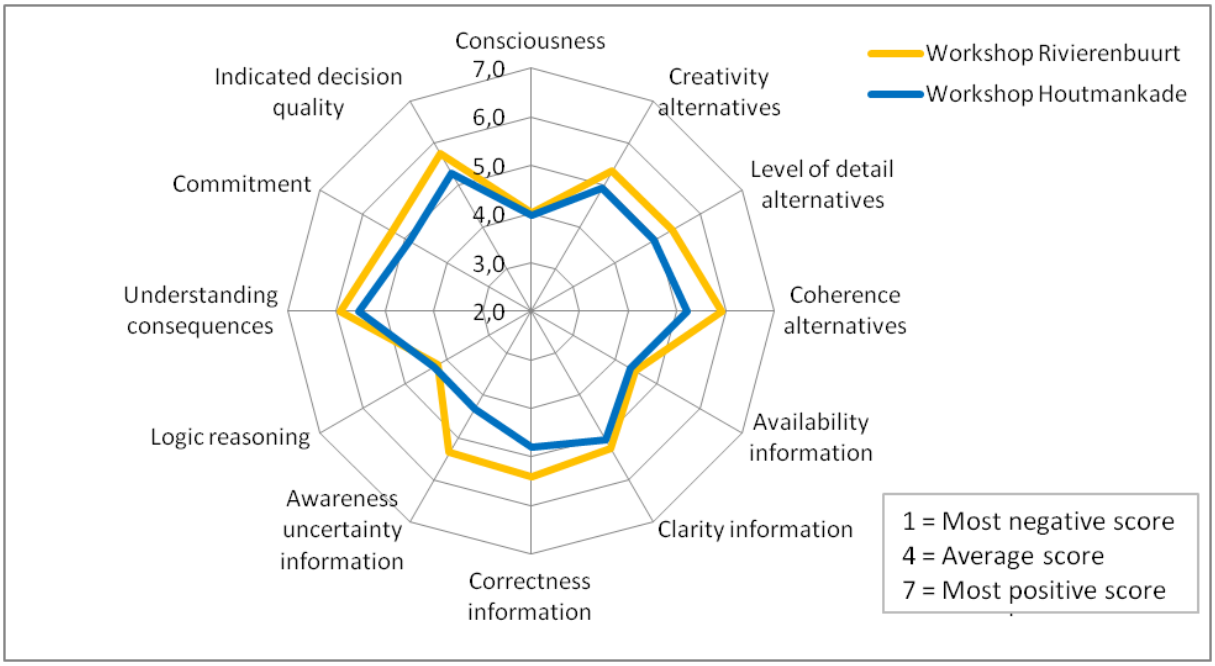


Figure 14: Average scores of decision quality elements for the 3Di system split up per workshop

The participants that are using a model normally, so have a clear comparison model, rate some aspects different from those who are not using a water simulation model, see Figure 15. Participants using normally a model gave a higher score for their perception on the decision quality. Another difference between model users and non-model users is their opinion about the creativeness and level of detail of alternatives. This is possibly due to a higher knowledge of the participants about the subject. This can be similar for the consciousness, with more knowledge of the subject, finding more aspects of the decision will be easier. Participants using a model normally rated higher for awareness of uncertainty and the correctness of information. Interestingly, this is only due to participants of the Houtmankade. Only participants not using a model from the workshop Houtmankade rated low for these elements (see Figure 12).

Participants not using a model had a more positive opinion about the clarity of the information. They found the difficulty and the time to find information better than participants normally using a model did. This is unexpected because model users might have more experience with models, possibly they are more critically. Remarkably, this is only for model users of the workshop Rivierenbuurt (see Figure 12) and not for Houtmankade, although they all answered these questions.

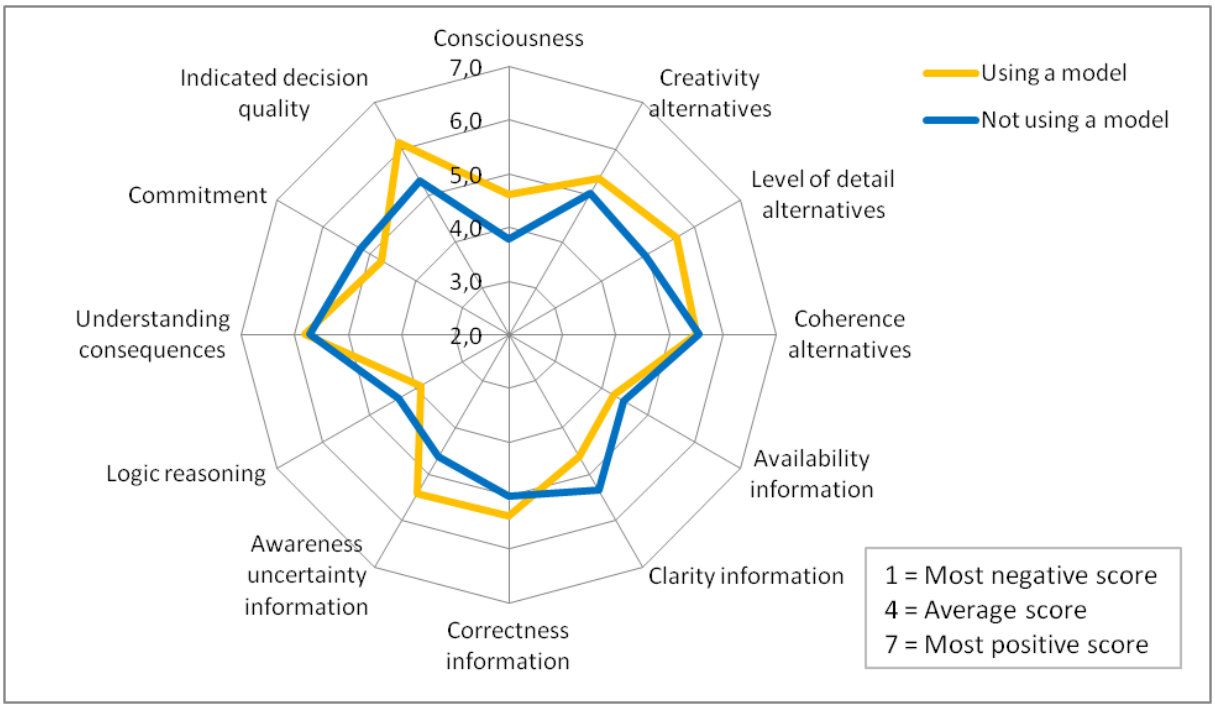


Figure 15: Average scores of decision quality elements for the 3Di system split up per reference situation

3.3. Difference in decision quality between reference situation and 3Di

The highest score for improvement by using 3Di was for the depicted decision quality (see Figure 16). Participants were asked if the decision quality was improved using 3Di in comparison with their reference situation. Only two participants gave a '4', so saw no difference between the decision quality of their reference situation and by using 3Di. Likewise, the other decision quality elements were almost all improved according to the answers of the questionnaire. Only the awareness of uncertainty of information was not improved, but stayed equal. The spread of most elements is quite high, for some ranging from the lowest score '1' till the highest '7'. The depicted improvement of decision quality elements is thus highly dependent of the individual opinion of participants of the study.

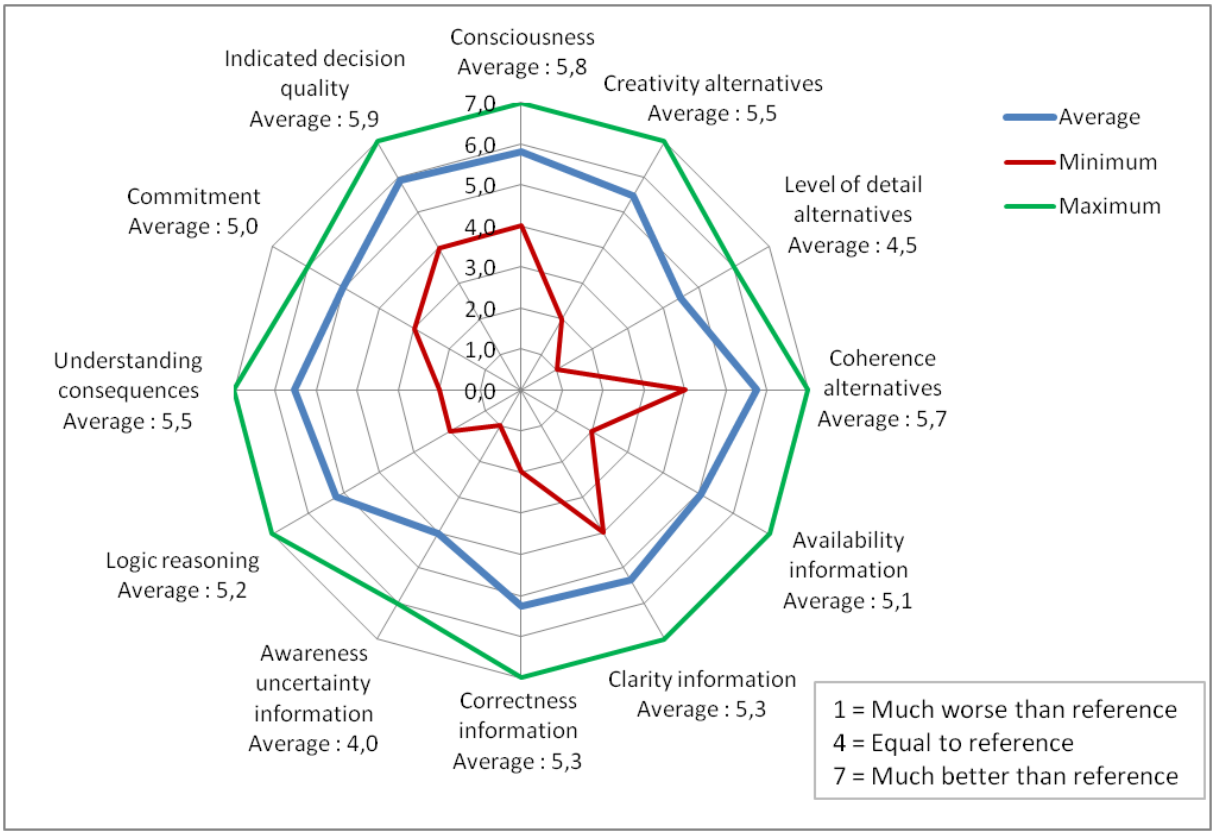


Figure 16: Average scores of both workshops of decision quality elements for the comparison between 3Di and the reference situation

More information can be obtained from a distinction between four groups of participants, per workshop and using or not using a model (see Figure 17). The outlying values for Houtmankade/using a model for logic reasoning, awareness of uncertainty of information, commitment and depicted decision quality are partly due to the low number of participants of that group. Only one participant answered the question about the commitment and logic with a number, the two other answered 'non-applicable', so these elements´ scores are not reliable. However, the three participants answered all the questions about awareness of uncertainty of information and depicted decision quality. These scores can thus be seen as a more reliable result. Knowing that, the score for awareness of uncertainty of information is very low for participants from the Houtmankade using a model normally.

Remarkable are the outlying values for four elements for both groups of the Houtmankade. For level of detail of alternatives, coherence, clarity of information and indicated decision quality,

participants of the Houtmankade using a model gave on average the highest score. In contrast, participants of the Houtmankade not using a model gave the lowest score. The average score for both groups of the Riverenbuurt are in between. In addition, for the elements about alternatives and information participants not using a model from the Rivierenbuurt workshop are more positive than participants using a model normally. This is the opposite for the results of workshop Houtmankade.

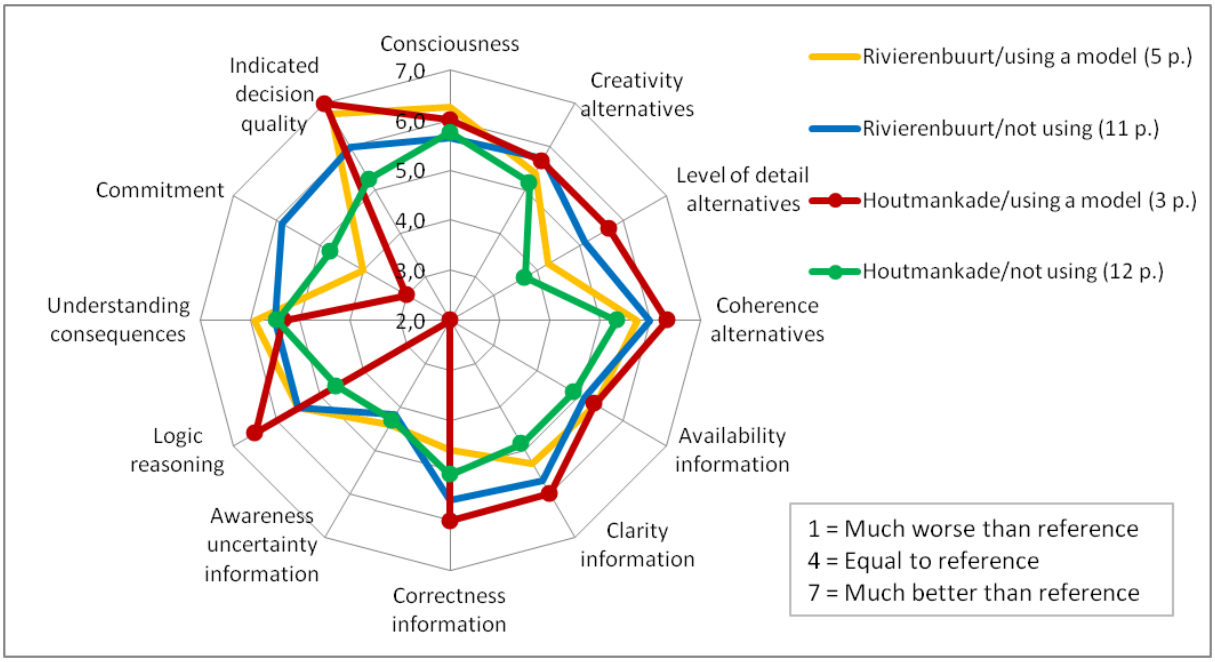


Figure 17: Average scores of decision quality elements for comparison between 3Di and the reference situation split up per workshop and reference situation

With a comparison of the two cases (Houtmankade and Rivierenbuurt) some causes for the scores can be found. In Figure 18 and Appendix F.4 can be seen that participants see more improvement of decision quality by 3Di for the case Rivierenbuurt than for the case Houtmankade. This trend cannot be seen in Figure 17, participants using normally a model found more improvement for most decision quality elements. These differences can be significant, however they can also be caused by the participants themselves. The model users are low in number, so the significance of these results is lower than for the non-model users. The result that non-model users of the workshop Houtmankade saw less improvement than those from the workshop Rivierenbuurt is thus more reliable.

The lower depicted improvement can be caused by the differences between the workshops. Discussions about topics beyond the scope of the workshop arose at the start of the Houtmankade workshop what led to less time and attention for the workshop. Furthermore, the atmosphere during the Rivierenbuurt workshop was more positive, participants took more enthusiastically part in the workshop. Another difference between the two workshops was the presentation at the beginning. The presentation of the 3Di system and Rainproof program was more detailed in the Houtmankade workshop, caused by different presenters (see section 2.5). This could have resulted in more critical participants about the correctness. It is expected that participants informed better about the correctness gave less widespread answer. Surprisingly, participants better informed about the correctness by the presentation (of the Houtmankade workshop) gave answers that were more widespread. The spreading in correctness was equal, but the spreading for awareness of uncertainty of information was higher. At last, there is a difference in background knowledge of the participants. 14 out of 16 participants of workshop Rivierenbuurt work normally with water hindrance, while only 10 out of 15 participants of workshop Houtmankade work normally with water

hindrance. Although, this will not results in large differences in depicted improvement because the difference in depicted improvement between participants normally working with water and participants not working with water is only small (see Appendix F.4).

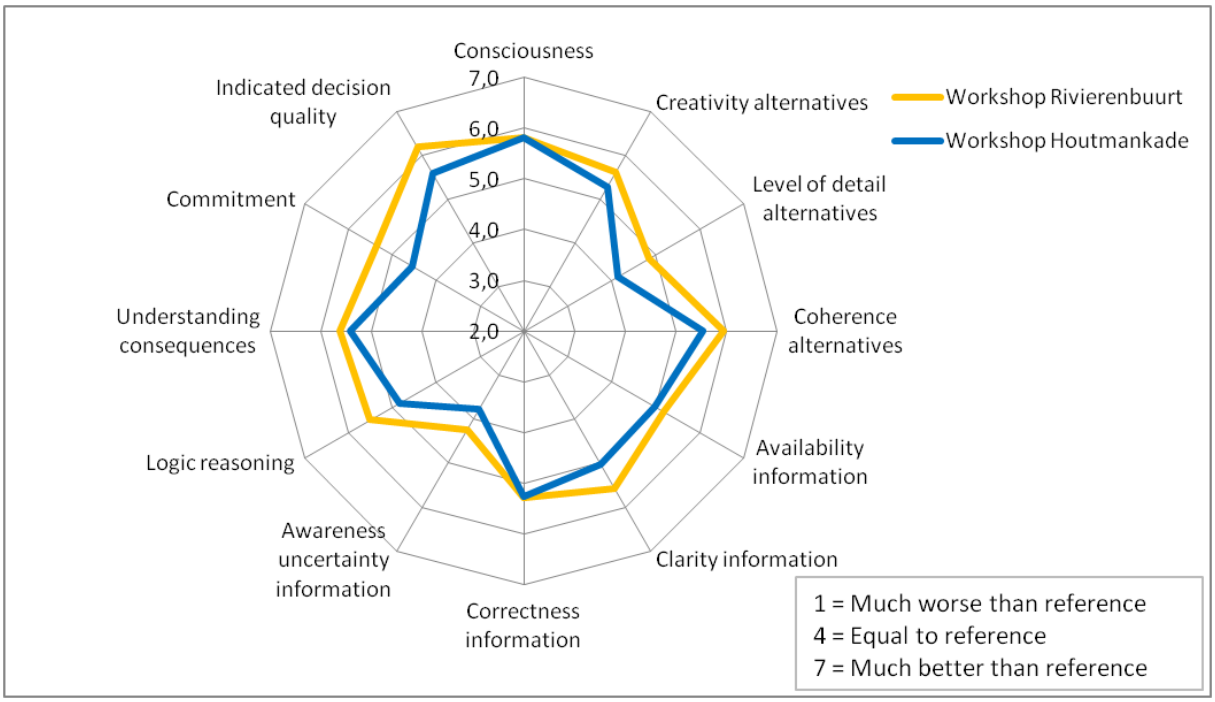


Figure 18: Average scores of decision quality elements for comparison between 3Di and the reference situation split up per workshop

Only eight out of the 31 participants indicated that they are using a model in their reference situation. The improvement of most decision quality elements was rated higher by participants using a model normally (as can be seen in Figure 19). Only the elements commitment and awareness of uncertainty of information were not rated as more improved by the model users than by the non-model users. If the workshops are considered apart (as in Figure 17 on the previous page) it becomes clear that this relation is different for the workshop Rivierenbuurt. Participants using a model thought only that the general decision quality and the consciousness were improved more than non-model users. For other elements there is only a small difference or model users think the decision quality is less improved. Expected is the high score of non-model users for commitment, their commitment is more increased than model users' commitment. This seems logical because the difference between no model use and 3Di use is high, what can result in high enthusiasm. In addition, the score for the other elements might be decreased for non-model users because their more limited understanding of the 3Di system.

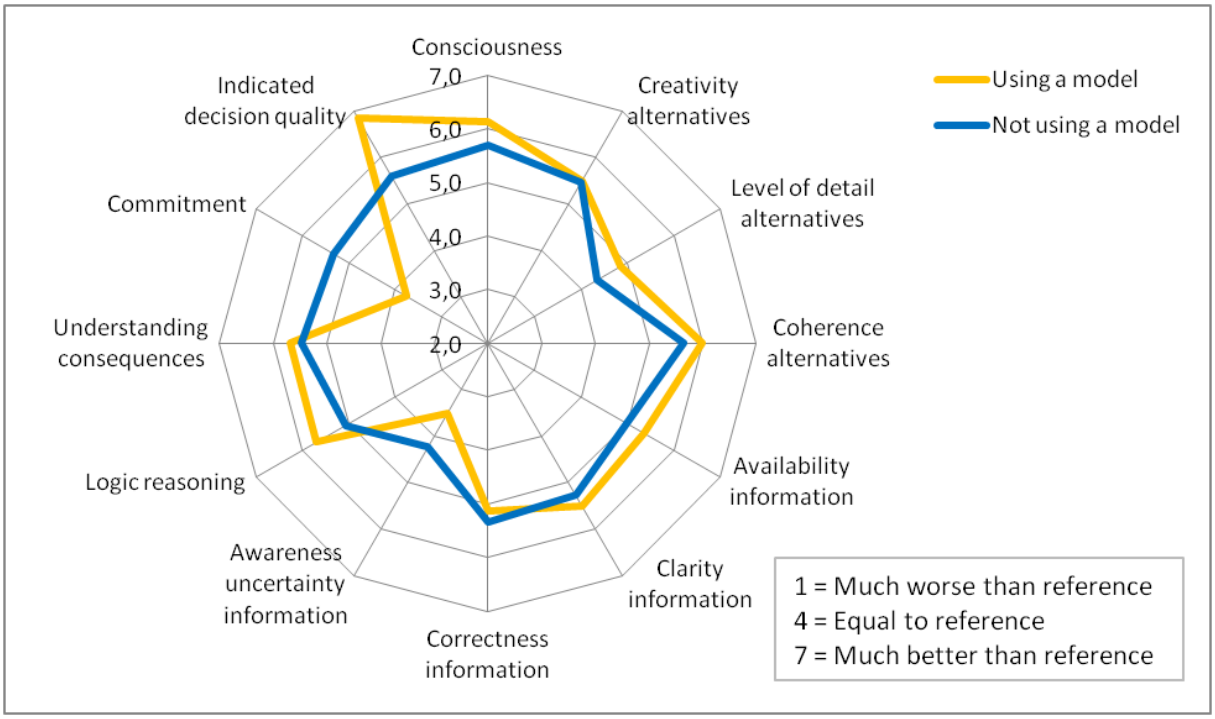


Figure 19: Average scores of decision quality elements for comparison between 3Di and the reference situation split up per reference situation

3.4. Result per criterion

The results per criterion are explained in this section. The score of a criterion can indicate a certain decision quality, besides that it can be caused by the setup of the workshops, the case, the participants or the 3Di version. See Appendix F for the exact answers of the participants and the exact scores for each criterion. In addition, an overview is given in the appendix of which questions of the questionnaire led to the scores for the elements.

Consciousness of perspectives

The opinion of participants of the workshops is that 3Di helps to make the perspective more conscious, it is rated 5.8 on average, while 4.0 is equal to the reference situation. Nobody thinks the number of aspects is decreased by using 3Di, because the lowest answer is '4'. The number of overlapping and the number of total aspects mentioned by participants cannot be compared with another model. However, it can be concluded that participants using a model mention more aspects and more overlapping aspects. In addition, they think the number of aspects they include increases more than for people not using a model in their reference situation. Participants using a model have thus more benefits of the 3Di system for this element.

Alternatives - Creativity and diversity of alternatives

Most participants state that they considered more alternatives because of the use of 3Di, the average score was 5.5. Only one participant rated this with '2' and three participants with a neutral '4'. The participants found thus that the 3Di system increases the creativeness and diversity in alternatives.

The participants listed alternatives during the workshops. Participants from the workshop Rivierenbuurt suggested alternatives as infiltration areas, rain barrels, diversion of flow direction and a different road profile. The participants were divided in three groups among which the creativeness and number of alternatives differed highly. Participants of the workshop Houtmankade were divided in four groups, each group listed around the same number of alternatives. Examples of

mentioned alternatives were an underground water basin, ditch along streets changing the road profile. An objective score for creativeness and difference of alternatives is hard to determine. However, it seems that participants of the Rivierenbuurt mentioned alternatives that are more creative. Examples are shop thresholds and alternatives seen from an administrative side as publishing data. Participants of the workshop Houtmankade suggested more alternatives that were given with the assignment, although sometimes on other locations. This difference resulted too from the questionnaire, participants of the Rivierenbuurt stated they have listed more new alternatives than participants of the Houtmankade.

Alternatives – Level of detail of alternatives

Participants indicated that the level of detail of alternatives was not much improved by 3Di. They answered the question on average with a 4.5, what is slightly above no difference with the reference situation. The answers are very widespread, so participants have very different opinions about this. One participant gave a '1' and three a '2', so some state that the level of detail was better in their reference situation. Participants commented during the workshops that the size of the implemented alternatives was quite large or took much time to implement, what made it difficult to add much detail. The level of detail of alternatives could thus be better, but is still a bit improved by 3Di. However, the participants were still satisfied with the level of detail of alternatives of the 3Di system itself (without comparing).

Alternatives – Coherence of alternatives

The participants state that using a strategy would be easier with 3Di, the average is 5.7, only three participants do not agree with this and give a neutral answer. When it is easier to use a strategy, coherence of alternatives will be higher. Use of 3Di will therefore increase the coherence of alternatives. Participants indicated that there was coherence between the sub-solutions during the workshops, nobody stated that it was not there. This was also shown by the final solutions, although some groups chose a final solutions consisting only of one sub-solution. The other groups suggested mostly a coherent combination of sub-solutions, the same kind of solutions or solutions that support each other. Examples are lowering road thresholds to lead water to a square and a combination of infiltration in a park and green roofs.

Information – Availability of information

The score for element availability of information is the results of two questions in the questionnaire, one about the availability of information by the model and one about possible missing information. Participants saw an improvement by 3Di for both of these questions. However four participants were missing more information than in their reference situation, these are all non-model users. Only two participants said they had more information in their reference situation. Still many participants were missing information in the 3Di system, ten participants found information missing. Examples of mentioned missing information are sewage data and flow directions, also more details as threshold heights were mentioned. However, the final score for the availability of information is positive because participants found there was enough information available.

Information – Clarity of information

The score for the element clarity of information is composed from two aspects, the time it took to find the right information and the level of difficulty of the using. Participants found that the use of the 3Di system improved both aspects, time and difficulty. Most participants rated the questions about these aspects with a '6' (agree). Eight participants saw (almost) no difference in easiness and seven participants saw (almost) no difference with their reference situation in quick using. The clarity of information is thus improved by using 3Di. In contrast, the participants of the Rivierenbuurt workshop that are normally using a model found on average no improvement of the clarity by 3Di. Although, they are still positive about the easiness and speed of the 3Di model itself. The 3Di model is thus not better structured than other models according to the participants, but

they are still satisfied. Besides that, the general structure of 3Di (without comparing) is rated quite well. They were very satisfied about the difficulty and quite satisfied about the time to find the right information.

Information – Correctness and explicitness of information

The score for this elements is composed of the results of two questions, one question about if the results was realistic and one questions about the level of detail. All participants stated on average that the correctness and explicitness was increased by using 3Di. Only two participants found the 3Di model less detailed than their reference. These participants are both using WOLK in their reference situation. The average scores for the different groups of participants are very similar. These groups are Rivierenbuurt/Houtmankade, using/not using a model and working/not working with water. Although participants were saw an improvement by using 3Di, the correctness of 3Di can be improved. They gave on average only a 4.8 for the correctness, even one person from the Houtmankade workshop gave a score of one.

Information – Awareness of uncertainty of information

The awareness of uncertainty of information is determined by a comparison between their awareness of the correctness of the reference method and how well they felt informed about the correctness of 3Di. They have not made the comparison by themselves as for the most other decision quality elements. The participants knew quite well about the correctness of both the reference method and 3Di, the average score is 5.3 for both questions. The awareness of uncertainty is therefore almost not increased. This is also represented in the score for this element (4.0), obtained by withdrawing both questions results. Logically is that participants using a model normally stated on average that their awareness of uncertainty is decreased (it scored 3.5), because they have more knowledge of the model they use normally. This low score is mostly due to participants of the Houtmankade using normally a model. They rated all three the awareness of uncertainty of their reference situation (much) higher than that of 3Di.

The participants found their knowledge correctness of 3Di sufficient, but a score for their awareness of uncertainty cannot be set if it is not well-known for them what the uncertainty is. However, Nelen & Schuurmans (2014) state that the 3Di system has a very low uncertainty if the integration of the sewage system is left out of consideration, but this cannot be checked. Participants of the Rivierenbuurt rated the veracity higher. So participants of the Rivierenbuurt workshop think they have a higher awareness of uncertainty of information, what does not mean that they have more knowledge of uncertainty.

Logic – Logic of reasoning

The element logic of reasoning is quantified by the participants' understanding of the final decision and how much intuitivity is used for the final decision. Participants indicated that they understood better why the final decision was taken than in their reference situation. Besides that, they stated that this decision was taken on a less intuitive way, what means more logic. Although, 11 versus 12 participants chose the option 'non-applicable' for these two questions. This might be caused by the vagueness of the term final decision, although this was explained on the questionnaire form.

The shift from another model to 3Di increases the clearness of the reasoning. This is because participants using a model normally saw a higher improvement in the logic of reasoning by using 3Di than participants not using a model normally. For the participants not using a model normally, the logic was not increased much. This might be due to an increased complexity by having more data (due to 3Di model use).

However, the participants are not very positive about the clear reasoning by 3Di itself. Eleven participants knew why the final decision was taken, others were neutral about this or did not answer the question. Besides that, only two participants stated that the final decision was not taken

in an intuitive way. Overall, the participants found the reasoning of the final decision not very clear during the workshops. Surprisingly it was still improved in comparison with their reference situation. The logic in the decision in their reference situation should be even lower than what they think of the logic resulted from using 3Di.

Logic – Understanding of consequences of alternatives

The understanding of consequences of alternatives is determined by two questions, one about the understanding of consequences for water, the other about other consequences. Knowledge about the effect of the alternatives on storm water has increased by most participants in comparison with their reference. Logically, the effects on other aspects have less increased according to the participants. There are no large differences for this element between the groups (Rivierenbuurt/Houtmankade, using/not using a model, working/not working with water normally). The improvement of logic on this sub-element is therefore quite reliable. Especially because the participants were also very satisfied with the understanding of consequences with using 3Di (without comparison with the reference situation).

Commitment to action or implementation

According to the methodology, commitment should be measured by the aspects 'satisfaction with the final decision' and 'agreement between the decision makers'. Unfortunately, only two participants answered what their own 'best final solution' was. A comparison between these answers and the group's best solution can thus not be made. The score for commitment is therefore only determined by the satisfaction. On average the participants stated that the satisfaction with the final decision was increased by 3Di. Regrettably, only 20 of the 31 answered this question. Participants using a model normally indicated on average a decrease of satisfaction, but this question was only answered by four participants of this group. Besides that, participants from the Houtmankade workshop were less satisfied with the final decision than participants from the Rivierenbuurt. This might be caused by the shorter time to find the final decision for that workshop.

Indicated decision quality

The indicated decision quality is no decision quality element, but is used to have an idea of the opinion of the participants about the decision quality in total. Participants were asked about if they found that the decision quality was improved by using 3Di, they answered on average that the decision quality was much increased. Even nobody said the decision quality was decreased and eight participants gave the maximum score for this. Participants using a model in their reference situation were very positive; six of them gave the maximum score. Participants of the Houtmankade were less positive than participants of the Rivierenbuurt workshop.

Participants were also asked if they would recommend the model. This was both asked for the situation of the workshop and other situations. Only one person from the total group will not recommend the 3Di system to someone to use it for a similar situation as in the workshops, the reason is the correctness of the model. All other participants will recommend the model for this use; they commented that the model gave much insight in water systems and problems. Many participants were neutral about recommending it for other purposes than the setup of the workshop. Still, other participants would recommend it for other purposes. Mentioned purposes were testing their own design, awareness, public space design and information for property owners.

4. Discussion

Due to the setup of the workshops, the participants or the model, comments should be made at the results. The quality of the study is divided in four types as listed by Yin (2009), construct validity, external validity, internal validity and reliability. Yin (2009) uses these types as criteria for judging the quality of a case study research.

4.1. Construct validity

Yin (2009) defines construct validity as the extent of identification of useful measures for the studied concepts. It is the extent to which the study is measuring what it should be. Examples of research aspects influencing the construct validity are the definition and specification of concepts and if questionnaire questions ask for fundamental information for the research questions (Leeuw et al., 2008). Aspects of the study that result in higher or lower construct validity are described in this section. This section is divided in validity of the decision quality elements, the workshop and the questionnaire.

4.1.1. Validity of decision quality framework

Most authors use a similar framework as used in this study to measure decision quality. However, some authors add costs and time, which are not included in this study. Costs can be excluded from the decision quality because in the strict definition of decision quality, the costs of the process or chosen measure are not involved. Lower costs will not lead to a higher quality decision. The costs can influence other elements, as commitment to action and the achievability of alternatives (although this element is not studied). Time of the process should also not be included in the decision quality. A long process can reduce the chance of implementation and attention for other elements can be reduced, as clarity of the purpose or logic of reasoning. However, time can also increase for example the awareness of uncertainty. The time of the process is therefore already included in other elements.

The main six elements of decision quality are used by different authors and are considered as complete. The used framework for the sub elements is mostly based on Mcnamee & Celona (2008). The sub elements of Mcnamee & Celona (2008) were rearranged to obtain the used sub elements and not all of them were taken up. The original sub elements were overlapping and were not including all aspects of the corresponding main element. An example is the sub element compelling alternatives, what overlaps with the element commitment. Other authors were also not complete or correct with their sub elements. Keisler (2011) uses only completeness, precision and accuracy as sub elements of information, while the uncertainty should also be involved.

Not all sub-elements and elements selected from literature are studied in this research. It was assumed that the clarity of the purpose, the definability of the scope, the achievability of alternatives and the values are not affected by using the 3Di model. After conducting the study, it became clear that sub-elements are not always directly affected by a model, but can also be indirectly affected. From a different working process, all aspects can change. Especially the sub-element achievability of alternatives was something that might be changed by model use.

The importance of each decision quality element is not equal. The total decision quality change by using 3Di is therefore difficult to determine. Nevertheless, all decision quality elements were seen as improved by 3Di, so knowledge about the importance of each individual decision quality is not needed. However, in this way not much can be said about how much the total decision quality is improved.

4.1.2. Validity of the workshops

The workshops were a simulation of the normal course of a decision-making process. The workshops simulated the steps 2 and 3 (development and comparison of alternatives and the decision) from the decision-making process described in the introduction (Figure 3). Participants were due to the simulation less prepared and had less knowledge about the problem than in a normal process. The steps identification of the problem and implementation were not passed during the workshops. More time is passed in a normal decision making process, in contrast to the time span of the workshops. Besides that, the decision makers are possibly not discussing altogether in a normal decision-making process. Some of them will normally not making decisions about water management specifically. In addition, when 3Di is used in a normal decision-making process, decision makers will be more used to the model. Studying a normal decision-making process can lead to the following differences in decision quality elements in comparison with this study:

- An increased creativeness and diversity between alternatives. Decision makers have more time and knowledge so will possibly come up with more alternatives.
- The availability of information will be increased because decision makers have more time to understand the 3Di system. This can be similar for the clarity of information and the understanding of consequences of alternatives, decision makers will have less difficulties using the system if the know it better.
- The awareness of uncertainty of information of the 3Di system will increase because there is more time available to ask questions and to try out the uncertainty.
- The commitment to action or implementation can reduce because the decision is spread over a longer time. In addition, the novelty of the model can increase the commitment.
- Changes caused by the workshop itself (not by the use of 3Di) will be reduced. This can be the commitment, consciousness and logic of the decision.

4.1.3. Validity in questionnaire results

Some ambiguity or vagueness in questions of the questionnaire could have led to an unintended spread in the answers. Some decision quality elements are therefore not measuring exactly what was intended. First, some general discussion points about the validity of the questionnaire will be discussed. After that, the validity of the specific questionnaire questions will be discussed.

Participants might have answered the Likert-scale from the questionnaire inconsistently. Each person can have a different interpretation of the meanings of the scores or answers just overall more positive or negative. It is tried to increase the validity by including descriptions of the Likert scale's numbers, so interpretation will be more equally. Besides, control questions were included to check the understanding of the questions. Although not all participants answered the control questions, it could be concluded that they understood it right in general. No answers were thus left out.

A distortion in the results of the questionnaire is caused by the comparison. Participants had to rate the difference with their reference situation, but this is quite difficult when it has to be done subjectively while the other situation only exists of memories. It cannot be said if this would have led to a better or worse decision quality due to the use of 3Di. Although it is expected that 3Di is rated as more positive by this method, 3Di is new and is the aim of the workshops. Participants will not say easily that it will not improve anything.

The presentations about 3Di and Rainproof were more detailed during the workshop about the Houtmankade than during the workshop Rivierenbuurt due to different organizers. The shortcomings of the model (as missing of the sewerage module) were presented in more detail. This could have led to a lower comparison score for all decision quality elements from the participants of the workshop Houtmankade. The results of the Houtmankade might thus be more reliable than the

results of the Rivierenbuurt workshop. The participants of the Houtmankade workshop saw less improvement by 3Di in comparison with their current situation than the participants of the Rivierenbuurt workshop.

Most questions were asked in a way that a positive answer lead to improvement by using 3Di. Mostly, people are more willing to agree with something than to disagree, so this could have led to a more positive score in advantage of the use of 3Di. 66 % of the total answers are positive (five, six or seven as answer, see Figure 20). The positive results for the improvement by using 3Di should therefore be decreased. Besides that, the used Likert-scale is an ordinal scale so the average of the answers is only an indication and cannot be seen as a definitive result. The spread of the answers for a question is therefore important to consider.

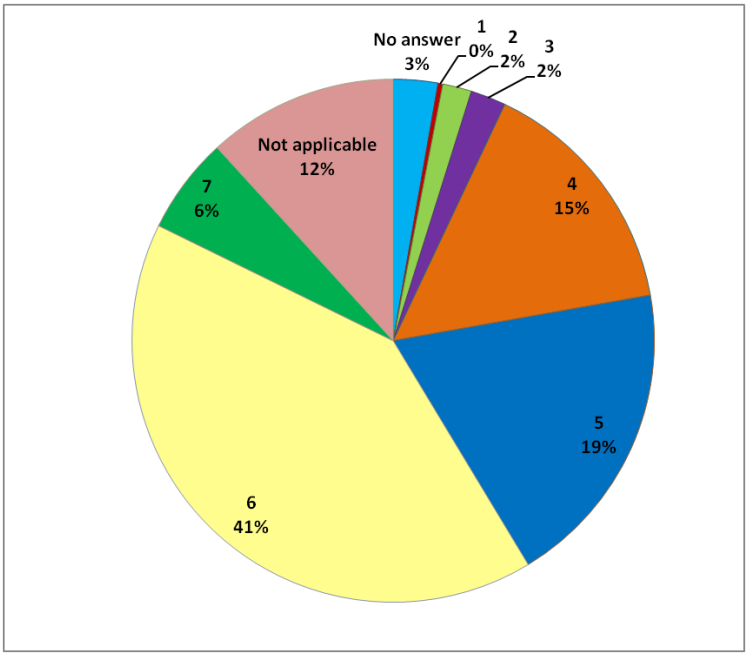


Figure 20: Distribution of answer options given

Some remarks about the questionnaire questions that influence the construct validity in relation to the decision quality elements they represent:

- The element awareness of uncertainty of information is difficult to measures with questions. The participants had to give a score for their awareness of uncertainty, but this is only what they think about it. The real degree of awareness can only be determined by comparing their knowledge with the real uncertainty of the model. Because the real uncertainty is not specified in detail, this element is not measuring what it should be.

- Another remark about the element awareness is the lack of a comparing question. Questions about possible improvement of decision quality were asked only for the other elements. The result for the element awareness of uncertainty is obtained by comparison of two questions (their knowledge of correctness of the reference method and their knowledge of correctness of the 3Di system). This leads to a different type of answer than for the other elements.

- Due to the low response on the question about the individual's preferred final decision, the commitment is only measured by the satisfaction with the final decision. This is not reflecting all parts of commitment, decision-makers should also have consensus for commitment. The true score for commitment could thus be different from the one measured in this study.

4.2. Internal validity

Internal validity is defined by Yin (2009) as the quality of the inferences in a case study. The investigator had to draw conclusions about events that cannot be directly observed based on interviews or other sources. When this is not done correctly, the internal validity is lower (Yin, 2009). Babbie (2007) describes the internal validity as the degree in which conclusions drawn from experimental results reflect accurately what happened in the experiment. The internal validity of the research method is low, because the main results are based on people's opinions. Opinions can easily change and can be affected by many aspects outside the scope of the research. The aspects that affect the internal validity are listed below:

- During the workshop, participants could have lost attention. This seemed not to be the case during the workshops, but can have had effects on the questionnaire results. This is because the participants had to fill in the questionnaire at the end of the workshop. Some of them might have been in a hurry. This is possibly one of the causes of the many 'non applicable' answers. Besides that, it can be the cause for the high number of '6' answers, participants might answer the same for each question if they want to finish quickly.

- Participants of the workshops could have had smaller knowledge of the 3Di model than the method they use in their reference situation. This can lead to different answers if the two are compared. For example for the sub-element awareness of uncertainty, participants could have answered the questions about this differently when they are more used to the model and know more about it. This is equal for the clarity of information, the correctness, the availability of information and the level of detail of alternatives. For most elements, this will lead to an even higher decision quality due to the use of 3Di. In contrast, this can lead to a lower decision quality for the element awareness of uncertainty.

- The consciousness of the perspective of the participants is hard to measure objectively. Participants have filled in issues for the element consciousness, but categorization of these aspects (necessary for counting), is very subjective. Furthermore, the number of aspects can depend on the enthusiasm of participants to fill out the questionnaire. They will put more effort in the questions if their commitment to the questionnaire is higher. The results of the element consciousness of the perspectives have thus a high uncertainty. However, this does not apply for the comparison of consciousness between the current situation and the use of 3Di, because this is not dependent on these categories.

- The questionnaire questions about the final decision (related to the elements logic and commitment) were possibly not interpreted as meant. This can be concluded from the high number of 'not applicable' answers that are given for the six questions about the final decision. Some participants have ignored all the questions about the final decision by answering it with non-applicable. Eight participants chose for all six questions 'non-applicable'. This can be caused by vagueness of the term "final decision" for the participants, they might have thought that there was no final decision during the workshops. The term was explained in the questionnaire but it might still have been unclear. Besides that, some groups were not focused on looking for one 'best' option, but were just discussing. Results for this element are therefore based on a low number of participants and are thus not very reliable.

4.3. External validity

Yin (2009) defines the external validity as the domain to which the findings can be generalized. Yin (2009) points out that this is an important problem for case studies. The external validity of this study is quite high, because the results are not so much influenced by executing the research in different projects or organizations. The current situation of decision-making can be very different

for other locations or organizations. The change in decision quality due to the use of 3Di will be very different if participants have different reference situations.

This study is at least valid for the situation that is studied:

- Decision-making processes in Amsterdam with involvement of both Waternet and the city council
- Projects were water management is not seen as the main goal
- Projects with only decision-makers of the municipality, so for example no inhabitants
- In the current situation no models or models as Infoworks and WOLK are used
- With use of the 3Di system with the version of June 2014
- A decision-making process with clear steps and a start and end point
- An urban storm water project

The sample of workshop participants is not random, however it represents a normal proportion for decision-making processes for urban projects in Amsterdam, because both people from the district council as Waternet are included. The co-organizer of both workshops invited the participants and based the invitations on the proportion in a decision-making system. Only those who were available at the time of the workshops and were interested enough in the subject came to the workshops. Although most invited people attended the workshops, no people from the department of traffic and infrastructure attended. They study is still representative for decision-making processes in Amsterdam, because in a normal decision-making process, these people are also not attending often.

The study is expected to be representative for similar processes in cities in the Netherlands with a similar large (physical) distance between design departments as in Amsterdam. Advantages in communication due the workshops between different organizations or departments are also valid for these cities. However, the study can be less generalized for smaller cities, cities were water and road departments are integrated and municipalities without cities. The scores for consciousness and commitment can deviate because of differences in the decision-making process and communication.

The results for the elements information, logic and alternatives can differ if other models as used in Amsterdam (WOLK and Infoworks) are used in the reference situation. If the elements information, logic and alternatives have a higher (or lower) quality in the reference situation, the comparison with 3Di will work out differently. Because of the same reason, most results are not valid for other water simulation models. The amount of information, and the possibilities of other models would be different. However, some other models can provide similar maps with an overview of the flooding problems. These models possibly also affect the decision quality elements consciousness and logic. Besides that, the use of a newer version of the 3Di system might lead to different results, because of changes in the functionalities or calculations.

The research is also valid if other steps of the decision-making process are included. This is because the decision quality of the total decision-making process is simulated by some of the decision-making steps in the workshop. Therefore, the results are less valid for decision-making processes that follow the rounds model and are thus not following steps clearly (Hommes, 2008). Nevertheless, the comparison of alternatives and choosing the final decision are also part of such decision-making processes, so the research results are still valid.

The study is not valid for water projects not concerning storm water. For example for flooding in rural areas, different results can be obtained for the level of detail and the consequences of alternatives, because larger and different alternatives will be used. In addition, the score for coherence between alternatives will be different.

The significance of the results of the interviews is quite low because not so much interviews are done. Especially conclusions about the general decision-making process in storm water management project are hard to see as a firm proof. There are many differences between decision-making processes in different storm water management projects, so this cannot be checked with only a few interviews. The reliability of interviews about the decision-making process in Amsterdam is increased by asking interviewees from different organizations the same questions. In this way, someone's answer was checked in another interview.

During a congress in Bonn it was suggested that model use can lead to an overload of information. Attendants listened to a presentation about 3Di first, after which a discussion was held. Members of different international municipalities stated that too much information was not useful in a model because that makes it more difficult to understand. This result was not seen in this research, but might be the case if more complicated models are used. Too much information can then lead to less clarity, because it is hard to find the right information. It is therefore not sure if this research is valid for the use of other interactive, detailed and fast water simulation model than 3Di. This could not be checked because there is not much known about such models besides the 3Di system.

Results are consistent with studies about other models, other kind of water project in other countries. Frick & Hegg (2011) found that users will have an increased confidence about situation analysis and decision-making using the D-PHASE platform, a meteorological model. This can be compared with the improved logic in the final decision and the understanding of consequences of alternatives due to using the 3Di model. The information availability, structure and interpretation was also improved by the D-PHASE model of Frick & Hegg (2011), what is similar to the improvement by the 3Di system. The consciousness of the perspective was increased by the use of participatory modeling according to Voinov & Bousquet (2010). According to Leskens et al. (2013), the 3Di system is also increasing the understanding of effects of measures, what is similar to the results of this study. The decision support system AQUATOOL was useful to identify the problem, screening alternatives and for an operational implementation process (Andreu et al., 1996). Arciniegas et al. (2013) found that a high information level of the model results in a lower understanding by the users. This conclusion was not supported by this study, the high amount of information was not seen as a problem of using 3Di. Hwang & Lin (1999) support the conclusion that more information decreases the decision quality, they state that even a small increase of information diversity or dimension can decrease the decision quality.

4.4. Reliability

Reliability is defined as the possibility of repetition of operations in the study, while the same results will be obtained (Yin, 2009). The reliability is high if another investigator can conduct the same study and comes up with the findings. The reliability is thus high if the research procedure is fully documented, what is done in this study.

31 participants were involved in the workshops, one person can thus make a large difference in the results and that makes the reliability low. Moreover, the sample of participants using a model in their reference situation is even smaller; only eight participants. The uncertainty in the results is therefore high. Small differences between groups of participants cannot be seen as significant. In addition, no significant conclusions can be drawn from a small increasing or lowering of decision quality elements.

The reliability of the study can be concluded from the comparison of the results of the workshop Houtmankade and Rivierenbuurt. Unfortunately for the reliability, these results were not fully similar. On average the scores for the Rivierenbuurt were higher than for the Houtmankade. However, most of the elements show the same trend for both workshops.

A repetition of the study can be done because most research steps are documented in detail. The preparation of the 3Di model is described, including the used maps and parameter values. The workshop materials are given in the appendix and can thus be performed in the same way by another investigator. Moreover, the translation of workshop (or questionnaire) results in decision quality element scores is fully documented. However, a repetition of the interviews will be more difficult due to the fact that they were semi-structured. The questions asked during the interviews are therefore highly dependent of choices made by the investigator during the interviews. More information could have been obtained from the first couple of interviews if the investigator had more knowledge about the projects and normal proceedings of a decision-making process.

5. Conclusions and recommendations

First the main and sub questions are answered in the conclusion. After that, recommendations are given for the further research, the model and the Rainproof program.

5.1. Conclusions

The main research question is answered with help of three sub questions. The answers on the sub questions are described next. After that, the main question is answered.

5.1.1. What is the current situation of decision-making in urban storm water management projects?

The study has found that storm water management projects in an urban environment are mostly included in elements of other projects with a wider goal. Water management aspects appear in projects in other fields, as road construction or public space projects. There is no direct need for implementation of solutions for water problems, so projects can connect to other projects in the city to reduce costs. Solutions for water management are therefore not the main subjects in projects in Amsterdam, but are involved in the process of other urban projects. The same conclusions can be drawn for the studied projects in other cities (Rotterdam and Zwolle), water management was not the main subject of these projects. Besides that, other programs similar to Amsterdam Rainproof are set up in other cities to stimulate the integration of water management (and city heat management) in other projects.

The responsibility for storm water is not felt by a specific organization in Amsterdam. Waternet is only responsible for water in the sewerage (responsible for 7 mm rain per hour). The city council or Waternet do not feel responsible for the remaining water. But the municipality has 'zorgplicht' to discharge rainwater falling on public space to the sewage, what means that they are approachable for it. Still, both organizations think the other should care for that. Solutions for water on the street are therefore mostly not integrated in projects in the city. For example for a road design, the city council of Amsterdam makes a design. This design is sent to other organizations that can make their changes in this after which it is sent back for approval. A standard design for water discharge is often used. The sewage system is integrated in a project by Waternet, but the design is mostly not taking the remaining water into account. It can be expected that there are similar problems in other cities because extreme rainfall events are only an issue recently. However, organizational differences can lead to better communication between the responsible organizations.

Water simulation models are not used often by organizations in Amsterdam. Infoworks is used by Waternet to simulate discharge to and in the sewage system. Besides that, some people use WOLK to identify problem locations. This conclusion for Amsterdam is confirmed by the interviews about projects in Zwolle and Rotterdam, suggesting its validity for other Dutch cities.

5.1.2. What is the decision quality using the 3Di system in urban storm water management projects?

Decision quality is in this research defined as the quality of the decision-making process, including the input information, the process itself and the final decision. The outcome of the decision is defined not to contribute to the decision quality. Decision quality is measured with eleven sub decision quality elements. Main subjects of these elements are the perspectives of decision makers, the used alternatives, the available information, the logic in the decision and the commitment to implementation.

A single score for the decision quality by using 3Di is not very useful. This is due to the absence of similar scores for decision processes using other methods or models. Therefore, the weak and strong points of the 3Di system are identified, which are valid for the use of 3Di for an urban storm water

management project involving municipal decision-makers. Participants were in general satisfied with the use of 3Di; no much negative remarks were made. Participants of the organized workshops were satisfied with all decision quality elements in the decision-making process using 3Di. The highest satisfaction is for the element 'understanding of consequences of alternatives'. The weakest elements are the availability of information and the logic of reasoning for the decision. Despite the high average scores for the elements level of detail of alternatives and correctness of information, some participants of the workshop disagreed with this and gave the lowest score.

5.1.3. What are the changes in decision quality elements in urban storm water management projects caused by using the 3Di system in comparison to the current decision quality in these projects?

The results of the workshops in Amsterdam show that decision quality is on average increased by the use of 3Di in comparison with the current situation. All elements of decision quality were seen as improved or were rated equally in comparison to the current situation. Most participants were not using a model in their individual reference situation; the use of 3Di is therefore mostly compared to the absence of using a water simulation model.

The decision quality is increased most on the elements of coherence of alternatives, consciousness of perspectives of decision makers and the understanding of consequences of alternatives. The quality has stayed equally for the element of the awareness of uncertainty of information. The level of detail of alternatives is increased only slightly. Besides these results based on decision quality elements, the participants of the workshops indicated an improved decision quality when it was asked particularly.

When a model is used in the reference situation, the improvement by 3Di is significantly larger than when no model is used for the consciousness of the perspective and logic of reasoning for the decision. In addition, this background of the participants resulted in a higher improvement in indicated decision quality. For respondents not using models in their reference situation, the improvement is higher for awareness of uncertainty of information and slightly for commitment.

5.1.4. Main question: What is the difference in decision quality of urban storm water management projects as Rainproof in Amsterdam caused by using water simulation models as the 3Di system in comparison to the current decision quality of these projects?

Use of the 3Di system is improving the decision quality in urban storm water management projects in comparison to the current situation. This applies both for a current situation with and without model use. The improvement of the decision quality by 3Di is tested for projects were water management is integrated as a part of the project in Amsterdam. The decision quality will also be improved by using 3Di for similar projects in other cities, although the results can differ for projects focusing mainly on water problems.

An improved decision quality does not necessarily mean that the outcome of the decision will be better by 3Di, the success of the outcome depends on many other variables. Although, an improved decision quality increases the chance of a good outcome, so 3Di will increase the chance of a good outcome.

5.2. Recommendations

This section describes recommendations for additional research, urban storm water management projects and 3Di.

5.2.1. For additional research

This study is only done for a small part of the water simulation models and decision-making processes. The improvement of the decision quality can be optimized by a specific use of 3Di or a specific design of the decision-making process. In this study, the decision-making process is kept as similar as possible to the current situation, although it was influenced by the setup of the workshops. Additional information about decision quality can be obtained if a similar study will be done for:

- The simulation of two similar decision-making processes in a workshop, one without the model and one with use of the model. In this way the comparison is not fully based on the decision-makers opinions. However, the current method of decision-making should be easy identifiable for this.
- Projects in a different stage of the decision-making process, for example at the start when no public space designs are prepared. Then, more changes in the project can be made by new information obtained by the model.
- A project were inhabitants are involved in the decision-making process. The effects of the use of 3Di for lay people can be studied then, as compared to effects on professional only in the current situation.
- The complete version of 3Di, with integration of sewage and interactive adaptation of land use, it is expected that this will increase the decision quality even more.
- Other water models that are currently under development could be studied. Possibly, they give better results than the 3Di system does.
- Using the 3Di system in a real decision-making process to exclude the distortions caused by the organization of the workshops and the short time of using 3Di. The study should then last over a long period.

If studies for other projects, models or locations are done, it might be necessary to define the importance of each decision quality element. In this research, this was not necessary because all decision quality elements were rated positive. A conclusion could thus be drawn even when no importance was assigned.

5.2.2. For urban storm water management projects for extreme rainfall

The study concludes that 3Di increases the decision quality of urban storm water management projects for extreme rainfall. Thus, the use of 3Di can be a helpful for identifying and solving of water hindrance problems in the city of Amsterdam. The use of 3Di will increase the quality of decisions and therefore increases the chance for a good outcome or results of the project. The use of the 3Di system increases the creativity of alternatives. Besides that, the decision-makers see more logic in the decision and the chance of implementation is higher due to more commitment. In this section is described where the 3Di system can best be used in the decision-making process and who can use it best.

The 3Di model as used in the study was already useful to enhance discussions between stakeholders and show many people the problems of the future. Due to the organized workshops, decision-makers who are not meeting normally, discussed together about water management problems. Hopefully, participants that are not working with water normally have increased their knowledge of water management by the workshop. This might result in an easier integration of water management in other projects in the city. It is therefore recommend organizing more of these workshops if the participants of the organized workshops see the advantages too.

Additionally, the 3Di system can be helpful to increase awareness among inhabitants of Amsterdam, which is one of the goals of Amsterdam Rainproof. This will increase the element values of decision quality (which is excluded from this study). The involvement of inhabitants is not tested in this research but was pointed out during the interviews. To this end, the 3Di system can be made accessible to the inhabitants, but this can have disadvantages too. Inhabitants will possibly not understand the system or will use it wrong. Better is to use 3Di to present a solution that can be executed by inhabitants. Or to use 3Di to present why a certain measure is executed somewhere. Giving access to the full 3Di system can be done in addition to this for inhabitants that want more information.

Also for the use of 3Di in decision-making processes with only decision-makers from the municipality, only the results can sometimes be enough. The 3Di system is suitable to be used by all people working on these projects, but it could be cheaper, easier or faster to use only parts of it. This takes away the interactivity, so will result in a lower decision quality. However, when interactivity is taken away, the improvement of some of the decision quality elements stays equally, as understanding of the decision and availability of information. It might also increase the low decision quality scores for clarity of information due to the reduced time and difficulty of using. For example, an analysis of bottlenecks and effects of alternatives can be done by experts, whereupon decision makers can use the results.

It could be helpful to use the 3Di system in the beginning of the process. The awareness of decision makers of the city can easily be increased with help of 3Di. Decision makers of public space are not always aware of future water problems, because their knowledge about it is limited. Decision-makers are willing to integrate solutions for water problems in the design, but they do not know how and that they should do it. Besides that, interviewees said that money was a very important stake in integrating solutions for storm water. Many decision-makers think they cannot integrate storm water solutions without additional money. More knowledge of water management by use of 3Di in a project may give them insight in possibilities of integration. With smart integration of storm water management solutions in current projects, no large sums of money are necessary.

It became clear during the research that neither Waternet nor the municipality of Amsterdam did feel the responsibility of water on the street. Both organizations saw the other as responsible. The integration of water management in other projects in the city of Amsterdam would therefore be improved when this responsibility is better defined.

5.2.3. For the 3Di system

The level of detail of alternatives was a decision quality element that was not improved much by using 3Di. This element can be increased by adding more possibilities to insert alternatives. During the workshops and in the questionnaire, participants stated that they missed some possibilities. These were inserting sets of standard alternatives, changing a road layout by changing the profile or implementing speed bumps easily.

The availability of information can also be increased according to the workshop results. Participants of the workshops asked for information about flow directions for an easier analysis of bottlenecks and possible locations of solutions. Besides that, they missed information about threshold heights to have the opportunity to see which buildings are flooded. In addition, many participants of the workshops missed the sewage module. This integration (as already planned by developers of 3Di) will increase the availability of information.

The score for the decision quality element ‘awareness of uncertainty of information’ could be improved although the score has a low validity. The correctness of the model is not described now in detail and no examples of comparison with a real floods are known. The awareness of uncertainty of information will be increased when a comparison with the reality can illustrate the correctness.

Another way to increase this is to give information about the deviation in the model results. Participants of the workshops were also asking for more information about correctness in the questionnaire.

In the 3Di system, alternatives cannot easily be saved and implemented repeatedly, this results in a lot of time lost by working on this. The possibility of saving the results and viewing them later would therefore be very helpful. The possibility of saving it as a ‘movie’ can also be helpful to show other the results of a measure quickly.

6. Bibliography

Aksoy, L., Cooil, B., & Lurie, N. (2011). Decision quality measures in recommendation agents research. *Journal of Interactive Marketing*, *25*, 110–122. Retrieved from http://www.sciencedirect.com/science/article/pii/S1094996811000028

Akter, T., & Simonovic, S. P. (2005). Aggregation of fuzzy views of a large number of stakeholders for multi-objective flood management decision-making. *Journal of Environmental Management*, *77*(2), 133–43. doi:10.1016/j.jenvman.2005.02.015

Al-Sabhan, W., Mulligan, M., & Blackburn, G. . (2003). A real-time hydrological model for flood prediction using GIS and the WWW. *Computers, Environment and Urban Systems*, *27*(1), 9–32. doi:10.1016/S0198-9715(01)00010-2

Amsterdam Rainproof. (2014). *Programmaplan Amsterdam Rainproof*.

Andreu, J., Capilla, J., & Sanchis, E. (1996). AQUATOOL , a generalized decision-support system for water-resources planning and operational management, *177*, 269–291.

Arciniegas, G., Janssen, R., & Rietveld, P. (2013). Effectiveness of collaborative map-based decision support tools: Results of an experiment. *Environmental Modelling & Software*, *39*, 159–175. doi:10.1016/j.envsoft.2012.02.021

Arnbjerg-Nielsen, K., Willems, P., Olsson, J., Beecham, S., Pathirana, a, Bülow Gregersen, I., … Nguyen, V.-T.-V. (2013). Impacts of climate change on rainfall extremes and urban drainage systems: a review. *Water Science and Technology : A Journal of the International Association on Water Pollution Research*, *68*(1), 16–28. doi:10.2166/wst.2013.251

Arvai, J. L., & Froschauer, A. (2010). Good decisions, bad decisions: the interaction of process and outcome in evaluations of decision quality. *Journal of Risk Research*, *13*(7), 845–859. doi:10.1080/13669871003660767

Baaren, M. van. (2010). *Amsterdam Waterbestendig*. Amsterdam: Zwaan. Retrieved from https://www.waternet.nl/media/164375/amsterdam waterbestendig.pdf

Babbie, E. (2007). *The practice of social research* (11th ed.). Belmont: Thomson Wadsworth.

Bender, M. J., & Simonovic, S. P. (1997). Consensus as the measure of sustainability. *Hydrological Sciences Journal*, *42*(4), 493–500. doi:10.1080/02626669709492049

Boroushaki, S., & Malczewski, J. (2010). Measuring consensus for collaborative decision-making: A GIS-based approach. *Computers, Environment and Urban Systems*, *34*(4), 322–332. doi:10.1016/j.compenvurbsys.2010.02.006

Bredenhoff-Bijlsma, R. (2010). *Policy development under uncertainty: a framework inspired by cases of water management*. University of Twente.

Consortium 3Di Waterbeheer. (2014). *3Di inzichtelijk*. Consortium 3Di Waterbeheer.

Craswell, E., Bonnell, M., Bossio, D., Demuth, S., & Giesen, N. (Eds.). (2007). *Integrated Assessment of Water Resources and Global Change*. Dordrecht: Springer Netherlands. doi:10.1007/978-1-4020-5591-1

Davern, M. J., Mantena, R., & Stohr, E. A. (2008). Diagnosing decision quality. *Decision Support Systems*, *45*(1), 123–139. doi:10.1016/j.dss.2007.12.012

Dorland, R. van, & Jansen, B. (Eds.). (2007). *Het IPCC-rapport en de betekenis voor Nederland Het IPCC-rapport en de betekenis voor Nederland*. De Bilt/Wageningen: PCCC.

Ellis, J. B., Scholes, L., & Revitt, D. M. (2009). *Evaluation of Decision-Making Processes in Urban Stormwater Management* (pp. 1–38). Retrieved from http://www.switchurbanwater.eu/outputs/pdfs/W2-2_CBIR_RPT_D2.2.3a_Evaluation_of_decision_making_processes_in_urban_SWM.pdf

Fraenkel, L., Street, R. L., & Fried, T. R. (2011). Development of a tool to improve the quality of decision making in atrial fibrillation. *BMC Medical Informatics and Decision Making*, *11*(1), 59. doi:10.1186/1472-6947-11-59

Frick, J., & Hegg, C. (2011). Can end-users' flood management decision making be improved by information about forecast uncertainty? *Atmospheric Research*, *100*(2-3), 296–303. doi:10.1016/j.atmosres.2010.12.006

Ge, M., & Helfert, M. (2006). A Framework to Assess Decision Quality Using Information Quality Dimensions. *ICIQ*. Retrieved from http://mitiq.mit.edu/ICIQ/Documents/IQ Conference 2006/Papers/A Framework to Assess Decision Quality Using Information Quality Dimensions.pdf

Gemeente Amsterdam. (2013). Uitgangspunten bij de herprofilering Houtmankade - Gemeente Amsterdam. Retrieved May 22, 2014, from http://www.amsterdam.nl/parkeren-verkeer/nieuws-onderdelen/nieuws-houtmankade/herprofilering/uitganspunten/

Gersonius, B., Nasruddin, F., Ashley, R., Jeuken, A., Pathirana, A., & Zevenbergen, C. (2012). Developing the evidence base for mainstreaming adaptation of stormwater systems to climate change. *Water Research*, *46*(20), 6824–35. doi:10.1016/j.watres.2012.03.060

Giupponi, C., Jakeman, A. J., Karssenberg, D., & Hare, M. P. (Eds.). (2006). *Sustainable management of water resources*. Cheltenham: Edward Elgar Publishing Limited.

Goosen, H., Janssen, R., & Vermaat, J. E. (2007). Decision support for participatory wetland decision-making. *Ecological Engineering*, *30*(2), 187–199. doi:10.1016/j.ecoleng.2006.11.004

Grünig, R., & Kühn, R. (2009). *Successful Decision-making. Successful Decision-making (Second Edition): A Systematic Approach to Complex Problems* (pp. 1–239). Berlin, Heidelberg: Springer Berlin Heidelberg. doi:10.1007/978-3-642-00854-2

Habes, B., Lesterhuis, T., Jagt, B. van der, & Huizer, S. (2014). *Amsterdam Rainproof: Verificatie WOLK-analyse*. Hogeschool van Amsterdam.

Hammond, M. J., Chen, A. S., Djordjević, S., Butler, D., & Mark, O. (2013). Urban flood impact assessment: A state-of-the-art review. *Urban Water Journal*, 1–16. doi:10.1080/1573062X.2013.857421

Hazelrigg, G. A. (2003). Validation of engineering design alternative selection methods. *Engineering Optimization*, *35*(2), 103–120. doi:10.1080/0305215031000097059

Heikkila, E. J., & Huang, M. (2013). Adaptation to Flooding in Urban Areas: An Economic Primer. *Public Works Management & Policy*, *19*(1), 11–36. doi:10.1177/1087724X13506559

Hommes, S. (2008, December 12). Conquering complexity:dealing with uncertainty and ambiguity in water management. University of Twente. Retrieved from http://doc.utwente.nl/60258/1/thesis_S_Hommes.pdf

Howard, R. (1988). Decision analysis: practice and promise. *Management Science*, *34*(6), 679–695. Retrieved from http://mansci.journal.informs.org/content/34/6/679.short

Howard, R. (2007). The foundations of decision analysis revisited. In *Advances in decision analysis: From foundations to …*. Retrieved from http://books.google.com/books?hl=en&lr=&id=3Th66ed9tNoC&oi=fnd&pg=PA32&dq=The+foundations+of+Decision+Analysis+Revisited&ots=ciJKjc0lpW&sig=79OMN_2YfUX9Dewn2jHfJkUVCW4

Huitema, D., Kerkhof, M. van de, Ovaa, E., & Bos-Gorter, L. (2009). Innovative approaches to public participation in water management. In S. Reinhard & H. Folmer (Eds.), *Water policy in the Netherlands* (pp. 225–247). Washington: Resources for the future.

Hwang, M., & Lin, J. (1999). Information dimension, information overload and decision quality. *Journal of Information Science*, *25*(3), 213–218. Retrieved from http://jis.sagepub.com/content/25/3/213.short

Janssen, R., & Uran, O. (2003). Presentation of information for spatial decision support: A survey on the use of maps by participants in quantitative water management in the IJsselmeer region, The Netherlands. *Physics and Chemistry of the Earth, Parts A/B/C*, *28*(14-15), 611–620. doi:10.1016/S1474-7065(03)00107-4

Jefferies, C., & Duffy, A. (2011). *SWITCH Transtion manual*.

Jensen, E. (2007). Sensemaking in military planning: a methodological study of command teams. *Cognition, Technology & Work*, *11*(2), 103–118. doi:10.1007/s10111-007-0084-x

Jha, A., Bloch, R., & Lamond, J. (2012). *Cities and Flooding*. Washington DC: The World Bank.

Keisler, J. (2011). Portfolio Decision Analysis. In A. Salo, J. Keisler, & A. Morton (Eds.), *Portfolio Decision analysis: Improved methods for resource allocation*. New York, NY: Springer New York. doi:10.1007/978-1-4419-9943-6

Klok, T. M. (2012). *Modelling of stormwater overland flow in urban areas*. University of Twente.

Kluck, J., Hogezand, R. van de, Dijk, E. van, Meulen, J. van der, & Straatman, A. (2013). *Extreme neerslag: Anticiperen op extreme neerslag in de stad*. Amsterdam: Kenniscentrum Techniek.

Krosnick, J. A., Judd, C. M. C. M., & Wittenbrink, B. (2005). The Measurement of Attitudes. In D. Albarracin, B. T. Johnson, & M. P. Zanna (Eds.), *The Handbook of Attitudes*. Mahwah: Lawrence Erlbaum Associates. Retrieved from http://psycnet.apa.org/books/11352/055

Leeuw, E. D. de, Hox, J. J., & Dillman, D. A. (Eds.). (2008). *International Handbook of Survey Methodology*. EAM. doi:10.4324/9780203843123

Leskens, J. G., Brugnach, M., & Hoekstra, A. Y. (2013). Climate proof cities: application of an Interactive Water Simulation Model in Urban Water Management, a case study in Amsterdam.

Leskens, J. G., Brugnach, M., Hoekstra, A. Y., & Schuurmans, W. (2014). Why are decisions in flood disaster management so poorly supported by information from flood models? *Environmental Modelling & Software*, *53*, 53–61. doi:10.1016/j.envsoft.2013.11.003

Lu, P., & Stead, D. (2013). Understanding the notion of resilience in spatial planning: A case study of Rotterdam, The Netherlands. *Cities*, *35*, 200–212. doi:10.1016/j.cities.2013.06.001

Matheson, D., & Matheson, J. E. (1998). *The Smart Organization: Creating Value Through Strategic R&D*. Retrieved from http://books.google.com/books?hl=nl&lr=&id=v3MsPzCzlSsC&pgis=1

Mcnamee, P., & Celona, J. (2008). *Decision Analysis for the Professional* (4th ed.). SmartOrg.

Mintzberg, H. (1976). The structure of'unstructured'decision processes. *Administrative Science …*. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&profile=ehost&scope=site&authtype=crawler&jrnl=00018392&AN=4021438&h=rkBl3R%2FlNDH%2F%2FMIPZR9nsCjJw0nUrMXhA%2Bl%2F5%2FZ%2Faf58msu1q3dFXcYSyxJU%2FruQCP2WzhZQCthkV6cGSCOL8A%3D%3D&crl=c

Morss, R. E., Wilhelmi, O. V., Downton, M. W., & Gruntfest, E. (2005). Flood Risk, Uncertainty, and Scientific Information for Decision Making: Lessons from an Interdisciplinary Project. *Bulletin of the American Meteorological Society*, *86*(11), 1593–1601. doi:10.1175/BAMS-86-11-1593

Nelen & Schuurmans. (2013a). *3Di Casestudy West-Friesland*.

Nelen & Schuurmans. (2013b). Beschrijving modelinstrument en werkstappen modelering_v7. Nelen & Schuurmans.

Nelen & Schuurmans. (2014). 3Di website. Retrieved February 24, 2014, from www.3di.nu

Pligt, J. van der, & Blankers, M. (2013). *Survey-onderzoek : De meting van attitudes en gedrag*. Amsterdam: Boom Lemma Uitgevers.

Raghunathan, S. (1999). Impact of information quality and decision-maker quality on decision quality: a theoretical model and simulation analysis. *Decision Support Systems*, *26*(4), 275–286. doi:10.1016/S0167-9236(99)00060-3

Ramos, M. H., van Andel, S. J., & Pappenberger, F. (2013). Do probabilistic forecasts lead to better decisions? *Hydrology and Earth System Sciences*, *17*(6), 2219–2232. doi:10.5194/hess-17-2219-2013

Rijnstraat-Zuid - Stadsdeel Zuid. (n.d.). Retrieved May 14, 2014, from http://www.zuid.amsterdam.nl/wonen_en/parkeren_en_verkeer/president/rivierenbuurt/rijnstraat-zuid/

Shared Decision Making Programme. (2012). *Measuring Shared Decision Making - A review of research evidence*. Retrieved from http://www.rightcare.nhs.uk/wp-content/uploads/2012/12/Measuring_Shared_Decision_Making_Dec12.pdf

Sidlar, C. L., & Rinner, C. (2009). Utility assessment of a map-based online geo-collaboration tool. *Journal of Environmental Management*, *90*(6), 2020–6. doi:10.1016/j.jenvman.2007.08.030

Speier, C. (2006). The influence of information presentation formats on complex task decision-making performance. *International Journal of Human-Computer Studies*, *64*(11), 1115–1131. doi:10.1016/j.ijhcs.2006.06.007

Stelling, G. S. (2012). Quadtree flood simulations with sub-grid digital elevation models, *165*, 567–580.

Uittenbroek, C., Claasen, M., Drimmelen, C. van, Gans, K. de, Veur, W. van der, Hartog, P., … Monchen, E. (2013). Amsterdam waterstad. *PLANAmsterdam*, 24–29. Retrieved from http://www.overamstel.nl/publicaties/nieuws/zelfbouw-overamstel!/@697562/planamsterdam-7-2013/

Vagias, W. (2006). *Likert-type scale response anchors. Clemson International Institute for Tourism and …*. Clemson. Retrieved from http://scholar.google.com/scholar?hl=en&btnG=Search&q=intitle:Likert-Type+Scale+Response+Anchors#0

Ven, F. H. M. van de. (2012). *Case document climate proof cities*. Knowledge for Climate.

Voinov, A., & Bousquet, F. (2010). Modelling with stakeholders. *Environmental Modelling & Software*, *25*(11), 1268–1281. doi:10.1016/j.envsoft.2010.03.007

Wilson, R. S., & Arvai, J. L. (2006). Evaluating the Quality of Structured Environmental Management Decisions. *Environmental Science & Technology*, *40*(16), 4831–4837. doi:10.1021/es051932b

Yates, J., Veinott, E., & Patalano, A. (2003). Hard decisions, bad decisions: On decision quality and decision aiding. In S. L. Schneider & J. Shanteau (Eds.), *Emerging perspectives on judgment and decision research* (pp. 13–63). New York: Cambridge University Press. Retrieved from http://works.bepress.com/andrea_patalano/18/

Yin, R. K. (2009). *Case study research*. California: SAGE publications.

Appendix A. Selection of decision quality elements

The D-PHASE project (Demonstration of Probabilistic Hydrological and Atmospheric Simulation of flood Events in the Alpine region) is a research project where meteorological models are evaluated. D-PHASE is a visualization platform for an end-to-end forecasting system (Frick & Hegg, 2011). During the project time, the usability, accessibility and perception of the users was tested by questionnaires. The perceived trustworthy of the forecasts was increased and the uncertainty information was better understood than without using the D-PHASE platform. The motivation of participants increased. The information load was too much for some users and getting an overview of the area was not easy for some participants. No clear alternatives were used (Frick & Hegg, 2011).

Arciniegas et al. (2013) analyzed three decision tools, a set of three colored maps, a digital map that shows quantitative values on demand and a digital map that shows qualitative values on demand. They organized a workshop and measured the usefulness, clarity and impact on the decision process during this workshop. They concluded that the three tools gave different results for the information supplied (what influences the understanding), the difficulty and the clarity of the presented information, the time a tool was used. In addition, the difference between the individual decisions and the group decision varied.

AQUATOOL is a computer based decision support system for decision-making in complex basins with multiple reservoirs, aquifers and demand centers. Andreu et al. (Andreu et al., 1996) presents the decision support system as valuable for screening alternatives, acquiring operating guidelines, expanding the knowledge about the basin and determining the risks. In addition, the use of AQUATOOL contributes to a closer communication between the developers and the users of the model. As a results of this, the real problems are addressed (Andreu et al., 1996). In addition, priorities of users are better presented with a DSS. The last point Andreu et al. (Andreu et al., 1996) state is the increased enthusiasm due to the use of a state-of-the-art tool.

Leskens et al. (2013) executed two workshops with 3Di in Watergraafsmeer and Purmerend. With questionnaires the improvement of the decision-making process was evaluated. The study found that the model improves the understanding of the problem and the uncertainty in the model outcome by the users. Besides that, it helps focusing on effective measures, because results are directly identified. The understanding of effectiveness of alternatives is increased by the use of the model. Furthermore, the process can be optimized because alternatives can be changed during the process. The model supports also in collaboration between participants with different perspectives (Leskens et al., 2013).

In Table 1, an overview of the decision quality elements that can be changed by using a model are shown. For each study the mentioned changes are marked by a cross, this will not exclude a possible change in other elements, but only changes in the elements stated in that article. These sub elements are chosen to be measured in this study. The remaining elements will only be checked if it is expected that they change.

Decision quality element	Sub element	Used elements for research	D-PHASE (Frick & Hegg, 2011)	Non-digital and digital maps (Arciniegas et al., 2013)	AQUATOOL (DSS) (Andreu et al., 1996)	3Di (Leskens et al., 2013)
Decision framing	Clarity of the purpose					
	Definability of the scope					
	Consciousness of perspectives	X		X	X	X
Alternatives	Creativity and diversity of alternatives	X				X
	Level of detail of alternatives	X				X
	Achievability of alternatives					
	Coherence of alternatives	X				X
Information	Availability of information	X	X	X	X	
	Clarity of information	X	X	X	X	
	Correctness and explicitness of information	X	X		X	
	Awareness of uncertainty of information	X	X		X	X
Values	Values					
Logic	Logic of reasoning	X				
	Understanding of consequences of alternatives	X				X
Commitment	Commitment to action or implementation	X	X		X	X

Table 1: Overview of Decision Quality elements affected by a model in several projects

Appendix B. Attended meetings and interviews held

Type	Name	Other attendees	Date	Location
Interview	Laurence Peel		03-03-2014	Telephonic
Interview	Paula Bijlsma		09-04-2014	Council Offices, Zwolle
Consultation		Members of the group "Nieuwe Wibaut"	11-04-2014	Waternet, Amsterdam
Interview	Anne Leskens		15-04-2014	N&S, Utrecht
Interview	Jeroen Kluck		17-04-2014	HvA
Interview	Cees-Anton van den Dool		17-04-2014	N&S, Utrecht
Interview	Thomas Staverman		22-04-2014	Waternet, Amsterdam
Workshop	'Rivierenbuurt Rainproof maken' organized by Nieuwe Wibaut (program of the city of Amsterdam)	Waternet, district council Zuic, DIVV, IBA	08-05-2014	Amsteltrouw, Amsterdam
Interview	Leo Schulp		02-06-2014	District office Zuid, Amsterdam
Interview	Reindert Bant		06-06-2014	District office Zuid, Amsterdam
Congress	Resilient Cities organized by ICLEI		10-06-2014	Bonn, Germany
Interview	Peter Ulle		18-06-2014	District office West, Amsterdam

B.1. Interview Laurence Peels 04-04-2014

Laurence Peels, Projectmanager Benthemplein vanuit de Gemeente Rotterdam

Het interview is per telefoon afgenomen.

Project:
Het project Benthemplein is onderdeel van het project/programma waterpleinen. Het Benthemplein is hier een voorbeeldproject van. Bij het Benthemplein is er zowel een waterbergingsopgave als een behoefte aan meer aantrekkelijkheid. Het Benthemplein was een voornamelijk stenen plein. Dit is goed geschikt voor de combinatie berging en verbeteren van aantrekkelijkheid.

Alternatieven:
Vanaf het begin was het idee om een waterplein aan te leggen. Er waren geen andere alternatieven. Er zijn wel verschillende soorten waterpleinen, gekoppeld aan de problemen. Een voorbeeld van oplossen van overloop van singels is het Kleinpolderplein. Een klein waterplein met weinig berging is het Bellamyplein. Een waterplein met het water niet zichtbaar is het Johan Idaplein.

Model:
Het is bij Laurence Peels niet bekend welke modellen gebruikt zijn voor de bergingsopgave. Over het gebruik van modellen was wel veel discussie.

Besluitvorming:
De functioneel beheerder, deelgemeente Noord, Hoogheemraadschap en stadsbouwers waren betrokken bij de besluitvorming. Het jongerenpaneel was de initiatiefnemer van het project maar zij waren al snel niet meer betrokken omdat hun project ophield. Het belangrijkste besluitvormingsmoment was het vaststellen van het inrichtingsplan. Dit was een democratisch besluit. Ook de financiën waren belangrijke besluiten maar deze zijn veelal opgeknipt tussen verschillende personen/partijen, dus waren niet met een grote groep genomen. In 2010 was ook een participatietraject gestart, hierbij waren het jongerenpanel, de school, het lyceum, de kerk en het sportcentrum betrokken.

B.2. Interview Paula Bijlsma 09-04-2014

Paula Bijlsma, beleidsadviseur ruimte, planoloog. Coördinator Deltaprogramma binnen de gemeente Zwolle.

Project:
Geluidswal Stadshagen. De vinexwijk Stadshagen ligt in de Mastenbroekerpolder, omringd door dijkring 10. De rest van Zwolle ligt in een andere dijkring. De Mastenbroekerpolder ligt vrij laag en delen van de dijkring zijn niet meer op orde. Om Stadshagen heen wordt een weg gelegd in combinatie met een geluidswal, een combinatie van geluidswal en gevolgbeperkend wal. De vinexwijk zelf zal nog uitgebreid worden. Het project was een pilotproject (proeftuin van Deltaprogramma Nieuwbouw) en is niet ontstaan vanuit een bestaand probleem. Gekeken is naar hoe op korte termijn problemen op lange termijn kunnen worden voorkomen.

De aanleiding van dit project is de Deltaopgave, hiervoor wordt binnen de regio samengewerkt met Provincie Overijssel, veiligheidsregio, gemeente Kampen, gemeente Zwartewaterland en waterschap Groot-Salland. Paula is onderdeel van het kernteam. Het team heeft een langetermijnperspectief gemaakt, hoe kan je de deltaopgave integreren met de regio-opgave. Oftewel hoe kan de wateropgave geïntegreerd worden met ruimtelijke, economische en sociale opgave. Deze wateropgave in het gebied rond Zwolle is redelijk groot aangezien het een uniek gebied is, het 'afvoerputje' van een groot gebied. Met het Deltaprogramma veiligheid wordt gekeken naar de normering, kunnen er verschillende normeringen gebruikt worden bij een dijkring?

Alternatieven:
Omdat er niet vanuit een huidig probleem gewerkt is, waren alternatieven het bouwen van enkele een geluidswal, de toevoeging van gevolgbeperkende functie of het maken van een dijk. Er is besloten om er geen officiële dijk van te maken omdat dit te kostbaar is en juridisch lastig. Een dijk moet voor langere tijd bestand zijn tegen water en ook kan er niet zomaar iets op een dijk aangelegd worden (zoals een fietspad). In tegenstelling tot het ontwerp van een geluidswal is een kleilaag aangebracht aan de buitenkant en is het talud gewijzigd. De kosten van het aanleggen van de combinatie gevolgbeperkende wal en geluidswal zijn 4 ton tegenover de aanleg van alleen de geluidswal.

Nu moeten er nog keuzes gemaakt worden voor de gaten in de geluidswal, bijvoorbeeld zandzakken of opblaasbare objecten. Over die gaten is nog geen vast besluit gemaakt omdat de meekoppelkans gegrepen werd voor de aanleg en de gaten van dus van latere zorg zijn. Een ander besluit wat nog gemaakt moet worden is de aansluiting op de kering, dit kan bijvoorbeeld gedaan worden door gebruik te maken van een oude dijk, hier kan mogelijk in de toekomst ook meegekoppeld worden bij een ander project.

Besluitvorming:
De besluitvormers waren de mensen van het kernteam. Ook het projectteam Stadshagen, van de geluidswal, heeft belang. De bewoners van het gebied zijn niet betrokken geweest. Uiteindelijk moet de bevolking wel betrokken worden bij de Deltaopgave. Veel bewoners weten namelijk niet welke risico's ze lopen.

Model:
Er zijn wel berekeningen gemaakt voor de waterhoogte bij overstroming, maar dit heeft de provincie gedaan. Voor de hoogte van de gevolgbeperkende wal maakt de waterhoogte niet uit, aangezien de geluidswal al ruim hoog genoeg is. De waterhoogte bij overstroming is wel van belang geweest voor de plaatsing van de kleilaag. Ook is het van belang voor de hoogte van opvulling van de gaten in de wal.

Toekomst:
Het project kan deels een vervanging zijn van dijkversterking op andere delen van de dijkring. Door compartimentering is het minder hard nodig om de dijken bij compartimenten buiten de stad te versterken. De dijken moeten wel voldoen aan de basisnormering, maar op deze manier kunnen andere dijken een 'plus' gegeven worden.

Er wordt gekeken of op andere plekken rondom Zwolle en rondom de Mastenbroekerpolder een vergelijkbaar project gedaan kan worden, dit is echter op lange termijn. De gevolgbeperkende wal is op korte termijn nog niet noodzakelijk, het is gebouwd voor de lange termijn. Het is pas bekend of het project geslaagd is na een overstroming.

B.3. Interview Anne Leskens 15-04-2014

Anne Leskens, promovendus Universiteit Twente en werkzaam bij Nelen & Schuurmans

Project:
Betondorp Amsterdam. Bij dit project is gekeken wat er gebeurd als de Kopenhagenbui, 100 mm in een uur, valt in Betondorp in Amsterdam. Tijdens een workshop met beleidsmedewerkers is laten zien wat er gebeurd. Bijna het volledige gebied overstroomde, echter verschilde de waterdiepte sterk per locatie. Naast een visualisatie van bovenaf is ook een 3D-simulatie laten zien (voorstelbaar als een helikoptervlucht boven het overstroomde gebied). Zo werd het probleem duidelijk voor iedereen. Het doel van de case study was om te laten zien hoe je met 3Di kan werken. Het was niet een besluitvormingproces zoals dat normaal verloopt, want dan heb je geen model wat je direct kan aanpassen.

Alternatieven:
Vanuit andere projecten waren er al ideeën voor mogelijke maatregelen, zoals een waterplein, goten, een nieuw straatprofiel en groene daken. Met de deelnemers van de workshop is met 3Di gekeken wat het effect van de maatregelen is. Deels waren de alternatieven al voorbereid in 3Di, maar het werd voornamelijk tijdens de sessie aangepast. Een voordeel was dat suggesties van mensen ook direct in het model aangepast konden worden.

Besluitvorming:
Er waren alleen beleidsmensen bij de workshop aanwezig, geen bewoners. Een beslissing is tijdens de workshop uiteindelijk niet genomen. De beslissing is ook lastig in tijd te definiëren, er gaat namelijk veel vooraf aan de uiteindelijke beslissing. Één van de voorafgaande dingen is dat je eerst op hoofdrichtingen kijkt naar alternatieven. Daarna zullen de beste opties nog nader onderzocht moeten worden. Deze workshop zat dus redelijk aan het begin van het proces.

Model:
Het model was in de tijd van de workshop niet anders dan dat het nu is. Het zag er hooguit wat minder mooi uit en het was niet per internet beschikbaar. Maar het was niet echt anders. Het rioolstelsel was toen ook nog niet in 3Di geïntegreerd, maar dit was niet van belang omdat bij zo'n hevige regen het riool toch snel vol zit.

Toekomst:
De sessie was een innovatieproject, het stond los van het beslisproces in Betondorp. Echter zal de workshop wel effect gehad hebben op dat proces, met de informatie die de deelnemers verkregen hadden.

B.4. Interview Jeroen Kluck 17-04-2014

Jeroen Kluck is lector op de Hogeschool van Amsterdam en werkt bij Tauw als waterexpert. Jeroen heeft onderzoek gedaan naar het anticiperen op extreme neerslag, ook staat er nog meer onderzoek gepland, naast neerslag gericht op hittestress in de stad. Jeroen Kluck is ook betrokken bij WOLK, een overstromingsmodel ontwikkeld door Tauw.

In Apeldoorn heeft Jeroen meegewerkt aan een project over klimaatadaptatie in de stad. Bij dit project werd er met WOLK gekeken naar knelpunten van wateroverlast. Met verschillende partijen, rioleurs, wegbeheerder, groenbeheerder ed. is gekeken naar oplossingen. Niet alle knelpunten hoeven gelijk aangepakt te worden, maar de WOLK-kaart kan gebruikt worden als uitgangspunt voor de toekomst. Naast WOLK is ook InfoWorks voor het rioolstelsel gebruikt. In Apeldoorn is (anders dan in Amsterdam) de verantwoordelijkheid van water in het riool en op de straat niet gescheiden. Maatregelen die in Apeldoorn genomen zijn, zijn aanpassingen van verkeersdrempels, het leiden van water naar een park.

Bij extreme neerslag zijn oplossingen vaak heel evident, vooral voor experts, daar is het gebruik van een WOLK-kaart niet voor nodig. De kaart is wel een hulpmiddel om anderen te overtuigen wat er moet gebeuren. Ook is er vaak niet een expliciet doel, een norm met aantal millimeter regen wordt vaak niet gesteld. Er zijn nog veel onzekerheden dus het stellen van een duidelijke norm heeft ook geen zin. Zo is het bijvoorbeeld lastig te bepalen hoe vaak een huis mag overstromen.

WOLK is niet zo nauwkeurig dat je zeker weet wat een maatregel helpt, gemeentes hebben hier vaak ook geen behoefte aan. Dit is natuurlijk per gemeente anders, maar omdat het gaat om iets wat niet zo vaak optreedt, hoeft het niet exact, een simpele maaiveldanalyse is dan soms al voldoende. Het is lastig om de onzekerheid in een model te bepalen aangezien het erg afhangt van de hoeveelheid en locatie van de neerslag die valt, en die is natuurlijk erg onzeker.

Bij vergelijkbare projecten zijn er vaak geen duidelijke alternatieven waartussen gekozen wordt. Vaak zijn er wel een paar logische alternatieven, het is meer de keuze om het bovenstrooms, benedenstrooms of met een combinatie op te lossen. Bij sommige projecten zijn er echter wel duidelijke alternatieven te onderscheiden. Multicriteria-analyses worden bijna niet gebruikt bij dit soort projecten. Iets met een onduidelijk doel is niet geschikt voor een MCA.

B.5. Interview Cees-Anton van den Dool 17-04-2014

Cees-Anton, Water coördinator in Purmerend, uitvoeren van het Waterplan

Project:
In Purmerend is geen locatie met een specifiek wateroverlastprobleem. Wel zijn er projecten gericht op wateroverlast in de toekomst. In een workshop in 2013 (samen met Anne Leskens) is gekeken naar waar problemen met wateroverlast verwacht kunnen worden. De workshop hoorde niet bij een project in Purmerend. In een andere wijk in Purmerend is 3Di gebruikt om het effect van straatophoging te bekijken. Met 3Di is nu een eerste onderzoek gedaan waar er wateroverlast ontstaat bij een 100 mm bui. Het resultaat daarvan wordt gebruikt om met stedenbouw om tafel te zitten om te kijken of de ophoging handig is, of dat het beter anders kan. De straten moeten opgehoogd worden omdat het verzakt is en je dus ook dichter bij je grondwater zit, het moet eigenlijk weer terug naar de vroegere situatie.

Model:
Ze gebruiken normaal geen model om wateroverlast door te rekenen in Purmerend. De wijk moet gewoon geherstructureerd worden en het moet dus terug naar de ontwerpsituatie. Er is wel gevraagd door de gemeente om het eens door te rekenen met 3Di. De vraag is nu of stedenbouw daar ook mee in zee gaat, in de huidige situatie wordt het dus niet doorgerekend.

Besluitvorming:
Het is lastig te zeggen of ophoging zorgt voor meer of minder wateroverlast. Straten fungeren heel duidelijk als verzamelplek voor het water, dus waarschijnlijk hebben huizen meer wateroverlast na straatophoging. Het is nog de vraag in hoeverre de stedenbouwers van hun plan afgebracht worden. Misschien hebben ze hele goede redenen om de ophoging wel uit te voeren.

Betrokken bij de besluitvorming zijn Ontwerp & Beheer, de ontwerpers , de afdeling beheer en projectleiders en nog anderen. De ontwerper vraagt aan de afdeling beheer of ze reactie willen geven over het ontwerp, omdat ook kabels en leidingen daar liggen en de afdeling beheer het uiteindelijk ook moet beheren. Als er veel opmerkingen zijn komt er een overleg anders niet. Het feit dat er communicatie is, is al nieuw voor Purmerend. Het is goed dat het ontwerp naar alle beheersdisciplines gaat, beheerder vuilnisbakken, beheerder groen ed.

B.6. Interview Thomas Staverman 22-04-2014

Thomas Staverman werkt bij het team Assetmanagement Afvalwater van Waternet. Daarbinnen is hij onderdeel van de strategische groep die naar de middellange termijn van de riolering kijkt, tussen 2 en 10-15 jaar in de toekomst. Hij houdt zich voornamelijk bezig met de Amsterdamse stadsdelen Centrum en West, de Houtmankade ligt in West.

Rioleringsbeheer is in Nederland een gemeentelijke taak. In Amsterdam wordt het riool namens de gemeente door Waternet beheerd. Waternet heeft taken van zowel het waterschap Amstel, Gooi en Vecht (alle waterschapstaken, zoals polderbeheer, dijkbeheer en rioolwaterzuivering) als van de gemeente Amsterdam (riolering en drinkwater). Binnen de afdeling riolering worden gebiedsstrategieën gemaakt waaruit volgt welke werkzaamheden er aan het riool gedaan moeten worden.

In principe heeft de gemeente zorgplicht voor het ontvangen van hemelwater (naast die van het ontvangen van stedelijk afvalwater en grondwater) en heeft het voordeel als er zo weinig mogelijk regenwater via het riool afgevoerd wordt. In tegenstelling tot andere steden zoals bijvoorbeeld Wageningen, zijn verschillende afdelingen ver van elkaar verwijderd in Amsterdam. Wegbeheer (stadsdelen) en rioleringsbeheer (Waternet) zitten organisatorisch ver van elkaar, terwijl je dit eigenlijk niet los van elkaar kunt zien.

Model:

Voordat we met 3Di aan de gang gingen hebben we ook een analyse met WOLK gedaan. In WOLK wordt aangenomen dat het riool al vol zit, dat is een heel realistische situatie, kolken kunnen niet werken, het riool is verstopt of er is teveel water.

Thomas Staverman heeft nog niets met 3Di gedaan en verwacht ook niet dat hij dat zal gaan doen. Wel is hij zeer geïnteresseerd in de resultaten van de berekeningen voor het bepalen van de toekomststrategie. Bij WOLK en Infoworks waren het ook collega's die de modellen maken en gebruiken, zij laten de resultaten aan hem zien. Wat opviel aan de resultaten van WOLK was dat aangenomen wordt dat het riool vol zit, wat dus leidt naar maatregelen bij wegbeheer. Hier zijn echter ook maar beperkte mogelijkheden, een stoep van een meter hoog is onrealistisch. Dit betekent dat er dus depressies in het maaiveld nodig zijn om het water te verzamelen.

Naast WOLK is 3Di een handig model om uit te zoeken wat precies op de knelpunten aan de hand is. Met WOLK zijn veel knelpunten al geïdentificeerd. Echter moet een model wel gekalibreerd worden met de werkelijkheid, bestaat de overlast ook in realiteit? Voordat WOLK beschikbaar was, was het niet fatsoenlijk mogelijk om een gecombineerde straat en rioolberekening te doen. Wel werden rioleringsmodellen als Infoworks gebruikt om onder andere de waking van het riool te testen. Sinds een paar jaar is er ook pas een Amsterdam-breed Infoworks-model beschikbaar door de verbeterde computerrekenkracht. Voor water op straat werd uitgegaan dat het goed is als de richtlijnen voor wegprofielen en kolken aangehouden worden.

Besluitvorming:
Voor besluitvorming over het wegontwerp is er weinig invloed mogelijk vanuit de afdeling riolering. Tekeningen en plannen worden heen en weer gestuurd, maar geïnitieerd van het wegbeheer. Vervolgens kunnen andere organisaties hun wenstracés intekenen en wensen over werkzaamheden uitspreken, dit wordt vervolgens gecoördineerd en uitgevoerd. Het is echter lastig wie nu bepaald of iets rainproof ingericht is, op dit moment is dat onduidelijk. In een kleinere gemeente is dat makkelijker omdat je dan dichter bij elkaar werkt.

Alternatieven:
Op dit moment wordt er in Amsterdam een uniforme catalogus gebruikt voor het wegontwerp, de Puccini-methode genaamd, maar daarnaast zijn nog veel andere keuzes mogelijk. Het wegprofiel kan steil, minder steil, met hoge of lage band. Ook keuzes voor verkeersdrempels kunnen wateroverlast veranderen. Soms maken obstakels zoals bomen een goed ontwerp lastig, omdat het maaiveldniveau daar dan niet verlaagd kan worden, dit heeft dan natuurlijk invloed op de alternatieven die gekozen worden.

Wensen model:
Het zou handig zijn om te kunnen zien in een model hoe water het riool instroomt. Er wordt nu vanuit gegaan dat water gelijkmatig het riool instroomt, maar dit hangt natuurlijk van de hoogteverschillen en obstakels op het maaiveld af. Daarnaast is niet bekend in een model waar de kolken staan en waar aansluitingen op het riool zitten, dit zou ingemeten kunnen worden bij de aanleg. Op die manier is het mogelijk steeds beter een afweging te maken of het riool of de weg aanpast moet worden. Dan kan ook bekeken worden waar de kolken geplaatst moeten worden, in plaats van dat de wegbeheerder de kolken iedere zoveel meter plaatst. Ook is onbekend hoeveel er afgevoerd wordt, hier zijn aannames voor. Bijvoorbeeld 70% afvoer bij elementverharding.

3Di zou gebruikt kunnen worden als databeheer, dan is het nuttig een overzicht te hebben van werkzaamheden. Bijvoorbeeld welke kolken al een nieuwe putklep hebben gekregen, of waar vuilwaterhuisaansluitingen zitten. Dit soort informatie zit nu vaak nog in een analoog bestand.

B.7. Interview Leo Schulp 02-06-2014

Leo Schulp is wijkbeheerder openbare ruimte van de Rivierenbuurt van Stadsdeel Zuid in Amsterdam.

In vergelijking met de andere wijken in stadsdeel Zuid is er weinig groen in de Rivierenbuurt, in de Pijp is echter nog minder groen. In de Rivierenbuurt zijn er nog wel groene lanen. Eigenlijk was er afgelopen tijd geen probleem met wateroverlast in de Rijnstraat, maar wel in de omliggende straten. In de Trompenburgenstraat kwamen putdeksels omhoog. Als er nu wateroverlast is in de Rijnstraat dan komt dat waarschijnlijk door boomwortelgroei in het riool. Als het heel hard regent staat de Rijnstraat normaal niet blank.

Het belang van Rainproof leeft nu ongeveer 2 jaar, als snel was duidelijk dat de druk het hoogst is in de Rivierenbuurt (van binnen Amsterdam).

Rijnstraat:
Voor de Rijnstraat is al een definitief ontwerp, er is ook een nieuw besluit over het tramspoor, het laatste stuk de tramspoor gaat weg. Er rijdt al geen tram meer door de Rijnstraat sinds 1 januari 2014. De eerste fase zal waarschijnlijk 19 augustus starten. Tijdens de herstructurering van de Rijnstraat zal er waarschijnlijk ook aan het riool gewerkt worden door Waternet. Waarschijnlijk is er geen aandacht besteed aan een handiger watertransport, zoals andere verharding. Het watertransport in de openbare ruimte is met het nieuwe ontwerp dan ook niet gewijzigd waar Leo Schulp van weet, dit is gewoon gedaan zoals dat altijd gebeurd. In de Rijnstraat wordt enkel een apart fietspad gemaakt, de autoweg zal dus smaller worden. Omdat er geen verhoogde trambaan komt is het mogelijk om een bredere stoep te hebben, wat voordelig is voor de winkeliers. Ook is het nu niet nodig de bomenrij te verplaatsen of verwijderen.

Het toepassen van een andere constructie, gunstig voor watertransport, zou misschien ook niet mogelijk zijn. Het liefst wil je bijvoorbeeld de pleinen anders inrichten en grijs vervangen door groen. Maar water dat niet in het riool gaat, moet natuurlijk naar het grondwater kunnen stromen. De grondwaterstand moet ook in de gaten gehouden worden, de grondwaterstand is behoorlijk hoog in de Rivierenbuurt.

Bij het Miep-Giesplantsoen zijn misschien meer mogelijkheden met inrichting voor water, hier zijn nog geen definitieve plannen voor gemaakt. Het zou zich kunnen lenen voor bijvoorbeeld een waterbuffer.

Leo Schulp krijgt weleens klachten van mensen dat hun tuin onder water staat. Soms komt het dan gewoon omdat omliggende tuinen hoger liggen of een groot deel van de tuin bestraat is. Het advies kan dan zijn dat ze de tuin moeten verhogen of groener moeten maken. Als je de openbare ruimte dus handigere in wilt richten moet je ook rekening houden met particulieren gronden.

De openbare ruimte kan beter ingericht worden met de Puccini-methode. Maar gewoon meer groen in de straat kan ook helpen. Op de Churchilllaan is dat bijvoorbeeld zowel handig voor wortelopdruk, dus minder onderhoud, maar ook voor een betere waterafvoer.

Modelgebruik:
Leo Schulp denkt niet dat er modellen voor watersimulatie gebruikt worden. Bijvoorbeeld bij het Miep-giesplantsoen worden in ieder geval wel plattegronden en andere kaarten gebruikt.

Leo Schulp heeft eerder nooit van het 3Di model gehoord. Het wordt in de toekomst mogelijk een tool die je kan gebruiken. Dat zou wel goed zijn, want je hoort steeds vaker dat het klimaat gaat wijzigen. Als je weet dat er een probleem komt moet je niet je kop in het zand steken. Leo Schulp denkt wel dat het voordeel heeft als je meer informatie hebt over waar precies het water komt. Er zou bijvoorbeeld iets gedaan kunnen worden met verhoogde of verlaagde verkeersdrempels, dat zijn relatief kleine aanpassingen. Je ziet met 3Di goed waar de problemen liggen en dan kan je daar vervolgens iets aan doen.

De presentatie van 3Di was duidelijk. Leo Schulp kon goed zien waar de problemen lagen. Hij zou ook zo niet kunnen bedenken wat er nog meer voor informatie in 3Di nodig is. Voor een beheerder van de openbare ruimte is het handig dat je het gebied kunt zien, je kan kiezen welke hoeveelheden vallen en je kunt de probleempunten zien.

Besluitvorming:
Het stadsdeel beheert de openbare ruimte, die identificeert de pijnplekken, waar onderhoud nodig is. Andere spelers in de grond, zoals waternet en kabelboeren, geven ook aan waar ze pijnplekken hebben. De partij die als eerst de locatie aanmeldt om aan te pakken, betaald vaak. De andere partijen gaan dan vaak mee, en betalen dan minder. Lastig is ook als het budget op is en partijen niet meer mee kunnen gaan, dan moet je daar op wachten.

Inspectierondes worden aangedragen vanuit het stadsdeel, het bestuur kiest vervolgens waar ze willen investeren. Met behulp van wenstracés worden vervolgens andere partijen betrokken. Volgens Leo Schulp zou een partij dan moeten aangeven dat een Rainproof inrichting nodig is, maar dat kost wel meer. Er is dus een meer-investering nodig voor Rainproof. De bestuurders zouden dat moeten besluiten, die moeten dat besluit aan de afdeling projecten voortzetten die bepaald hoeveel dat dan kost. Als er geen extra geld vrijgemaakt zal worden voor Rainproof zal er niets gebeuren.

Er is een verschil tussen klein onderhoud, groot onderhoud en herinrichting. Vaak wordt er door het stadsdeel gewoon onderhoud uitgevoerd in plaats van herinrichting omdat het traject dan sneller kan gaan. Een straat kan bijvoorbeeld gemakkelijk overnieuw bestraat worden met dezelfde of nieuwe materialen, dat heet dan gewoon onderhoud. Er wordt dan niets gewijzigd aan de inrichting (bijvoorbeeld geen wijziging in parkeerplekken en bomen) en het proces is eenvoudiger. Er hoeven namelijk minder partijen bij het besluit betrokken te worden.

Lastig is dat iedere speler zijn eigen budget heeft op dit moment. Bij de nieuwe inrichting van de gemeente zou dit verbeterd kunnen worden omdat meer partijen geïntegreerd worden. De beslissingen over inrichtingen komen waarschijnlijk centraal te liggen en niet langer bij de stadsdelen.

Het GVB bepaald welke tramlijnen behouden moeten blijven, welke rendabel genoeg zijn. Economische zaken wou het eigenlijk behouden vanwege bereikbaarheid van onder andere het hotel.

Volgens Leo Schulp is het belangrijk de juiste partijen bij elkaar te brengen om stukjes van Amsterdam handiger in te richten voor water, Rainproof maken, want daar wordt niet zo heel veel rekening mee gehouden. Ook bewoners zouden hierbij betrokken moeten worden.

Leo Schulp twijfelt over wie de verantwoordelijkheid heeft van water op straat. Als je weet dat de buurt bij regen overloopt heb je misschien wel de zorgplicht van de openbare ruimte als stadsdeel. Het is goed om je verantwoordelijkheid dan te nemen omdat je weet dat er toch problemen gaan komen. Enorme aanpassingen zijn misschien niet mogelijk, maar een handigere inrichting of adviezen wel. Er wordt natuurlijk wel deels rekening gehouden met watertransport, hoe hou je woningen droog en water het wegprofiel goed af op het riool. Daarnaast worden natuurlijk standaard berekeningen gedaan of het riool het aankan. Als er echter meer naar het riool stroom kan het riool dat natuurlijk niet zomaar aan, daar moet het riool ook voor aangepast worden. Hiervoor is belangrijk om goed te communiceren tussen de opdrachtgever en Waternet. Ook is het belangrijk dat de opdrachtgever niet automatisch voor een standaardinrichting te kiezen, vaak de puccinimethode, dat kost dan ook weer geld voor onderhoud.

B.8. Interview Reindert Bant 06-06-2014

Projectleider van de Rijnstraat, Stadsdeel Zuid van Amsterdam

<u>Besluitvorming Rijnstraat:</u>
De voorbereiding van het ontwerp van de Rijnstraat is gedaan door Tauw. Bij een project zoals de Rijnstraat wordt eerst een opdracht gegeven door de gemeente Amsterdam. Het stadsdeel schrijft deze opdracht uit en vervolgens voert een projectteam deze opdracht uit. Hiervoor wordt een voorlopig ontwerp gemaakt, deze wordt ook officieel vastgesteld door raad. Hierna worden bewoners bij het proces betrokken en wordt met hun input een definitief ontwerp gemaakt. Waternet en andere nutsbedrijven worden rond het voorlopig ontwerp betrokken, soms al voor het voorlopig ontwerp. Dit gaat dan met behulp van wenstracés. Er is bij de Rijnstraat geen gesprek geweest tussen het stadsdeel en waternet over het ontwerp met betrekking tot water, hierover is vooral mailcontact geweest.

Vanuit het projectteam wordt niet gekeken naar wateroverlast bij het ontwerpen van een weg. Soms wordt wel bij projecten door Waternet aangegeven dat de weg bijvoorbeeld verhoogd moet worden in verband met ligging van het riool. Hier wordt dan zoveel mogelijk aan voldaan, maar er wordt niet gekeken naar waterafvoermogelijkheden vanuit het stadsdeel.

Het huidige ontwerp voor de Rijnstraat is al zo definitief dat er weinig veranderingen meer aan gedaan kunnen worden, maar als er natuurlijk op dit moment nog aanpassingen gedaan kunnen worden zodat de waterhuishouding beter zal zijn, dan kan dat nog wel. Het zou bijvoorbeeld kunnen dat drempels naar zijstraten aangepast worden als blijkt dat deze het water blokkeren richting de zijstraten.

Het is niet heel duidelijk wie verantwoordelijk is voor het water op de straat. Waternet is verantwoordelijk voor het riool, maar wie vervolgens het water op de straat moet regelen is onduidelijk

<u>Model:</u>
Binnen het stadsdeel wordt niet met modellen voor water gewerkt. 3Di zou mogelijk wel nuttig kunnen zijn voor de werkvoorbereider, die onder andere het bestek maakt. Informatie over wateroverlast binnen de rivierenbuurt gebeurd door de beheerder openbare ruimte van de buurt. Deze geeft door wanneer er

bijvoorbeeld kelders overgelopen zijn. In de Rijnstraat zijn nooit echt grote problemen geweest met wateroverlast, geen overstroomde kelders. Wel zijn er parkeerplaatsen die regelmatig onder water staan.

Informatie over hoe het riool water afvoert van de straat en waarom dat problemen geeft zouden een nuttige toevoeging zijn voor het project.

B.9. Interview Peter Ulle 18-06-2014

Peter Ulle, coordinater ontwerp en beleid openbare ruimte

Peter Ulle heeft onder zich een team met ontwerpers openbare ruimte, voorbereiders en verkeerskundigen. Het stadsdeel ontwerpt plannen voor de openbare ruimte en voert ze uit. Het klimaat verandert, dus het wordt vaker droger en natter en er komen hittegolven. Het riool kan het niet meer aan, maar dat betekend ook wat voor bovengronds. Andere afdelingen in de stad denken er ook over na, maar er is weinig communicatie tussen. De klimaatverandering betekent als ontwerper dat de sponswerking vergroot moet worden, minder verharding en zoveel mogelijk groen. Groen helpt ook tegen de opwarming van de stad.

Besluitvorming:
Peter Ulle ontfermt zich niet actief over het onderwerp water, wel is het stadsdeel in gesprek met Waternet. Peter Ulle ziet water op straat als verantwoordelijkheid van Waternet, zij moeten zorgen dat het riool goed functioneert. De ontwerptekening van bijvoorbeeld een straat gaat tijdens het proces ook langs Waternet. Peter verwacht dat Waternet checkt of alles goed zit met waterafvoer bij het ontwerp.

Het ontwerp van een stadsdeel wordt na overleg met bewoners gestuurd naar Waternet, kabelbedrijven etcetera. Vervolgens sturen deze organisaties het ontwerp terug en maakt stadsdeel een definitief ontwerp en wordt het met een aannemer gemaakt.

Peter Ulle heeft nog niets met Rainproof gedaan. Wat nodig is zijn goede concrete tips voor ontwerp van de openbare ruimte. Rainproof is namelijk op dit moment geen issue.

Model:
Peter Ulle is onbekend met 3Di of andere watersimulatiemodellen. Hij verwacht dat 3Di nuttig zou kunnen zijn om knelpunten te identificeren in de stad. Hier kunnen ontwerpers dan op inspelen door bijvoorbeeld minder verharding toe te passen. Tot nu toe wordt er niet over wateroverlast nagedacht bij het ontwerp van het stadsdeel.

Houtmankade:
Peter Ulle is niet meer met het gebied Houtmankade/Spaarndammerbuurt bezig, die buurt is bijna af. Houtmankade is iets wat al heel lang op de lijst staat op aan te pakken vanwege fietsveiligheid. Afgelopen 15 jaar is de buurt daaromheen volledig aangepakt, enkele straten is niets mee gebeurd, maar staan ook niet meer op de planning. Peter hoort nooit klachten van bewoners van wateroverlast in de wijk, maar die klachten zouden er wel kunnen zijn. Op locatie van de school in de Spaarndammerbuurt komt woningbouw en een pleintje.

Appendix C. Workshop handouts

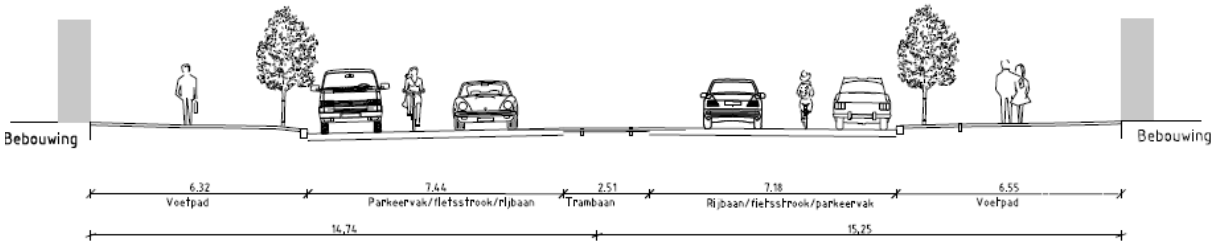
C.1. Workshop Rivierenbuurt

The participants received these maps and a satellite and street map of the area. The second and last maps are an overview of the alternatives that were already implemented in 3Di.

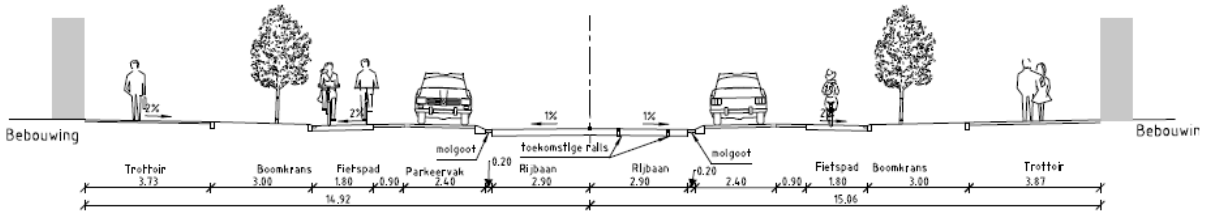
Case Handout

Door klimaatveranderingen worden er hevigere buien verwacht. Dit zal meer wateroverlast veroorzaken in de stad. In de workshop zal gekeken worden naar maatregelen tegen wateroverlast. Scenario's zijn:

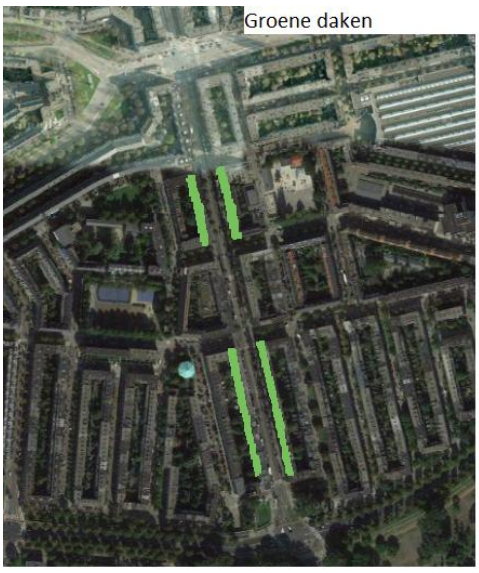
- Huidig wegontwerp
- Nieuw wegontwerp
- Nieuw wegontwerp zonder doorlopende stoep bij zijwegen
- Nieuw wegontwerp met doorlaatbare strook op voetpad en doorlaatbaar schoolplein
- Nieuw wegontwerp met groene daken langs de Rijnstraat



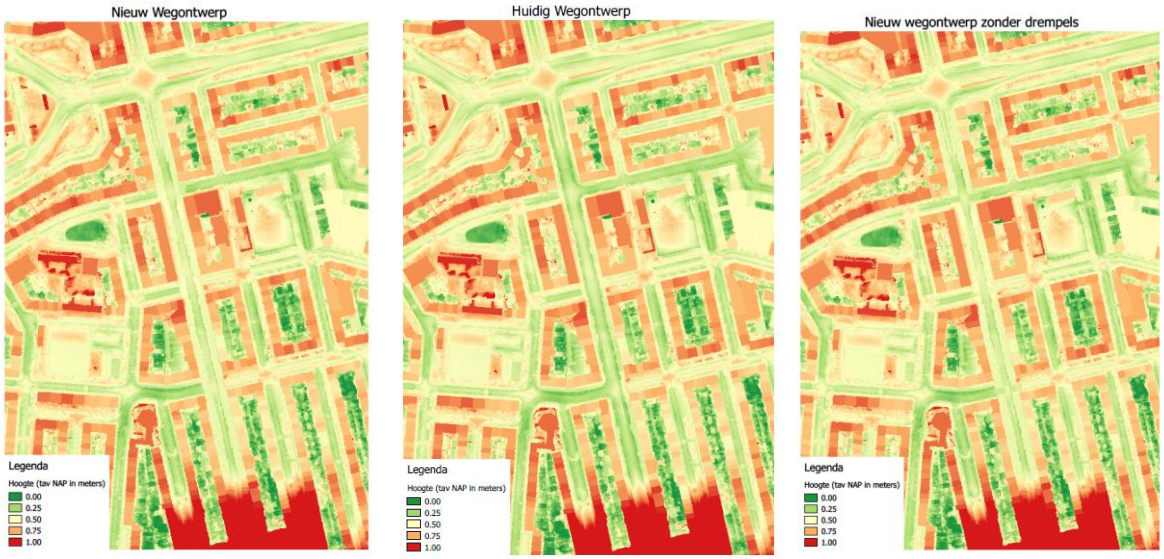
Huidig wegontwerp



Nieuw wegontwerp



Groene daken



C.2. Workshop Houtmankade

The participants received the case assignment and the maps given in this appendix. In addition a satellite photograph and street map of the area were given. The second picture is an overview of the alternatives that were already implemented in 3Di.

Case handout

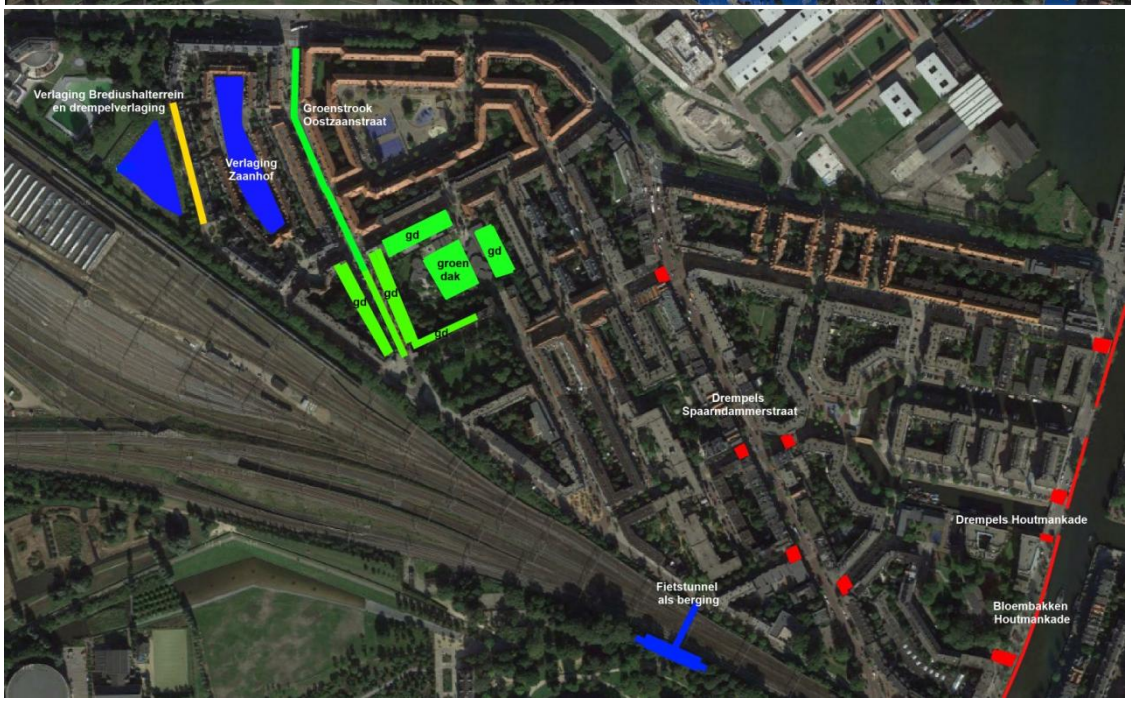
Door klimaatveranderingen worden er hevigere buien verwacht. Dit zal meer wateroverlast veroorzaken in de stad. In de workshop zal gekeken worden naar maatregelen tegen wateroverlast.

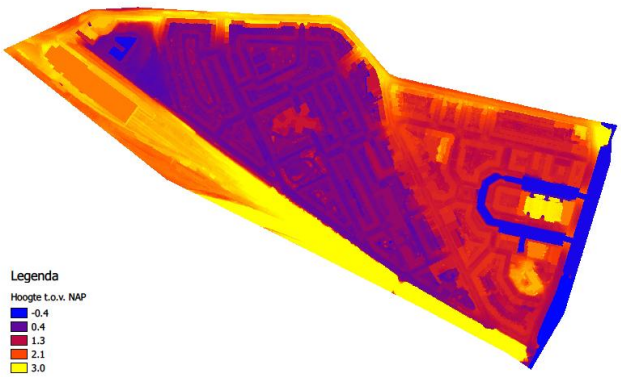
De Houtmankade wordt binnenkort vernieuwd, wat effect kan hebben op wateroverlast. Ook kunnen er andere maatregelen uitgevoerd worden in de wijk om wateroverlast te voorkomen. Vooral het lager gelegen gedeelte, de Spaarndammerbuurt kampt met wateroverlast.

Het doel van de workshop is om gezamenlijk na te denken over oplossingen voor wateroverlast door extreme regenval. Welke oplossingen zijn geschikt en hoe kan dit aansluiten bij huidige werkzaamheden. Voorbedachte alternatieven zijn:

- Verlaging terrein brediusbad
- Verlaging zaanhof
- Vergroening Oostzaanstraat
- Westerpark als berging (via fietstunnel)
- Wijziging drempels spaarndammerstraat
- Toepassing bloembakken langs de houtmankade
- Verhoging drempels houtmankade
- Groene daken bij het voormalige schoolterrein


100
mm


Verlaging Brediushalterrein
en drempelverlaging
Groenstrook
Oostzaanstraat
Verlaging
Zaanhof
gd
groen
dak
gd
gd
gd
gd
Drempels
Spaarndammerstraat
Drempels Houtmankade
Fietstunnel
als berging
Bloembakken
Houtmankade


Legenda
Hoogte t.o.v. NAP
-0.4
0.4
1.3
2.1
3.0

Appendix D. 3Di model choices

Values for the mode parameters:

- Minimum grid size used (Grid space) = 20,
- Maximum refinement level (kmax) = 4
- Refinement threshold (Bath_delta) = 1
- Maximum sensible bathymetry level (Bath_max) = 10
- Dams are find with bathymetry information (Guess_dams = 1)
- Initial water level = -0.4 meter NAP
- Euler implicit integration method used (Integration method = 0)
- Maximum number of nonlinear iterations in a single time step (Max_nonlin_iteration) = 20
- Number of predictor-corrector steps in a single time step (Num_pred_cor) = 1
- Minimal residual for convergence of water level solver (Convergence_eps) = 1e-05
- Flooding threshold = 0.01 m
- Lowest bathymetry point used (Open_link_check = 0)
- Advection on (Advection = 1)
- Priceman slots on (Priceman_slot = 0)
- Manning friction used (Friction type = 4)
- Friction coefficient = 0.026
- Simulation time step = 30 seconds
- Evaporation on (Evaporation = 0)

Appendix E. Questionnaire

3Di wordt vergeleken met uw referentiesituatie, het eventuele gebruik van een model en anders het niet gebruiken van een model.

Ik zat tijdens de workshop in groep:	
Heeft u al eerder met 3Di gewerkt? En zo ja, wat heeft u gedaan?	
Houdt u zich in uw normale werkzaamheden bezig met wateroverlast?	
Gebruikt u in uw werkzaamheden modellen of methodes om wateroverlast te bepalen? Zo ja, welke modellen of methodes zijn dit?	
Welke aspecten denkt u dat van belang zijn voor het probleem (wateroverlast)?	- Omwonenden - Klimaatverandering - - - -
Welke aspecten denkt u dat van belang zijn voor de oplossing (welke maatregelen genomen kunnen worden)?	- Omwonenden - Openbaar Vervoer - - - -

	1 Volledig oneens	2 Oneens	3 Een beetje oneens	4 Niet eens/ niet oneens	5 Een beetje eens	6 Eens	7 Volledig eens	Niet van toepas-sing
Door het gebruik van 3Di zie ik meer belangrijke aspecten van het probleem en de oplossing.	( )	( )	( )	( )	( )	( )	( )	( )
Ik heb andere dan de gegeven alternatieven overwogen tijdens de workshop.	( )	( )	( )	( )	( )	( )	( )	( )
	Bijvoorbeeld:							
Door gebruik van 3Di heb ik meer alternatieven overwogen.	( )	( )	( )	( )	( )	( )	( )	( )
Ik heb details aan de alternatieven toegevoegd (ook voor zelf bedacht alternatieven).	( )	( )	( )	( )	( )	( )	( )	( )
	Bijvoorbeeld:							
Door gebruik van 3Di heb ik alternatieven meer tot in detail kunnen uitwerken	( )	( )	( )	( )	( )	( )	( )	( )
Er is een samenhang tussen de gekozen sub-oplossingen (een bepaalde strategie).	( )	( )	( )	( )	( )	( )	( )	( )
	Strategie:							
Door gebruik van 3Di is het gemakkelijker een strategie te kiezen of toepassen.	( )	( )	( )	( )	( )	( )	( )	( )
Er was voldoende informatie beschikbaar.	( )	( )	( )	( )	( )	( )	( )	( )
In vergelijking met mijn referentiesituatie was er meer informatie beschikbaar door 3Di.	( )	( )	( )	( )	( )	( )	( )	( )
Mist er informatie die wel mogelijk is te geven? Welke?	( )	( )	( )	( )	( )	( )	( )	( )
	Welke:							

Door gebruik van 3Di miste ik minder informatie dan in mijn referentiesituatie.	( )	( )	( )	( )	( )	( )	( )	( )
De informatie werd gedetailleerd genoeg weergegeven.	( )	( )	( )	( )	( )	( )	( )	( )
De informatie was in 3Di gedetailleerder dan in de referentiesituatie	( )	( )	( )	( )	( )	( )	( )	( )
De tijd om de juiste informatie te vinden in 3Di was goed.	( )	( )	( )	( )	( )	( )	( )	( )
In vergelijking met de refentiesituatie duurde het met 3Di korter om de juiste informatie te vinden.	( )	( )	( )	( )	( )	( )	( )	( )
De moeilijkheidsgraad van de visualisatie was goed.	( )	( )	( )	( )	( )	( )	( )	( )
Het gebruik van 3Di is makkelijker dan gebruik van de referentiesituatie	( )	( )	( )	( )	( )	( )	( )	( )
Het 3Di model is waarheidsgetrouw.	( )	( )	( )	( )	( )	( )	( )	( )
Ik ben voldoende geïnformeerd over de waarheidsgetrouwheid van 3Di	( )	( )	( )	( )	( )	( )	( )	( )
Ik weet hoe waarheidsgetrouw de referentiemethode was.	( )	( )	( )	( )	( )	( )	( )	( )
Ik heb een realistischer beeld gekregen van water op de straat door 3Di.	( )	( )	( )	( )	( )	( )	( )	( )
Ik begrijp waarom de eindbeslissing genomen is (=het alternatief dat als beste gekozen werd).	( )	( )	( )	( )	( )	( )	( )	( )
Ik weet door 3Di beter waarom de eindbeslissing is genomen dan in de referentiemethode.	( )	( )	( )	( )	( )	( )	( )	( )
De eindbeslissing is genomen op een intuïtieve manier.	( )	( )	( )	( )	( )	( )	( )	( )
De eindbeslissing is genomen op een minder intuïtieve manier dan in de referentiesituatie.	( )	( )	( )	( )	( )	( )	( )	( )
Ik begrijp het effect van alternatieven op de wateroverlast.	( )	( )	( )	( )	( )	( )	( )	( )
Ik begrijp het effect van alternatieven op de wateroverlast beter door 3Di.	( )	( )	( )	( )	( )	( )	( )	( )
Ik begrijp het effect van alternatieven op andere gebieden dan wateroverlast.	( )	( )	( )	( )	( )	( )	( )	( )
Ik begrijp het effect van alternatieven op andere gebieden dan wateroverlast beter door 3Di.	( )	( )	( )	( )	( )	( )	( )	( )
Ik ben tevreden met de eindbeslissing.	( )	( )	( )	( )	( )	( )	( )	( )
Ik ben meer tevreden met de eindbeslissing door gebruik van 3Di.	( )	( )	( )	( )	( )	( )	( )	( )
Als u zelf de eindbeslissing had mogen maken, wat had u dan gekozen?								
Ik zou de tool aan iemand aanraden voor deze vorm van gebruik (besluitvorming over extreme regenval in de stad).	( )	( )	( )	( )	( )	( )	( )	( )
	Reden:							
Ik zou de tool aan iemand aanraden voor een andere vorm van gebruik	( )	( )	( )	( )	( )	( )	( )	( )
	Reden:							
3Di zorgt voor een hogere kwaliteit besluitvorming	( )	( )	( )	( )	( )	( )	( )	( )
	Reden:							

Appendix F. Results questionnaire

F.1. Question answers

1 = volledig oneens, 2 = oneens, 3 = een beetje oneens, 4 = niet eens/niet oneens, 5 = een beetje eens, 6 = eens, 7 = volledig eens.

	Average	Standard Deviation	No answer	1	2	3	4	5	6	7	nvt
Door het gebruik van 3Di zie ik meer belangrijke aspecten van het probleem en de oplossing.	5,8	0,7	1	0	0	0	2	4	22	2	0
Door gebruik van 3Di heb ik meer alternatieven overwogen.	5,5	1,0	0	0	1	0	3	9	14	3	1
Door gebruik van 3Di heb ik alternatieven meer tot in detail kunnen uitwerken	4,5	1,5	0	1	3	2	6	6	9	0	4
Door gebruik van 3Di is het gemakkelijker een strategie te kiezen of toepassen.	5,7	0,8	1	0	0	0	3	6	17	4	0
In vergelijking met mijn referentiesituatie was er meer informatie beschikbaar door 3Di.	5,4	0,9	1	0	0	2	2	6	17	0	3
Door gebruik van 3Di miste ik minder informatie dan in mijn referentiesituatie.	4,7	1,3	1	0	1	3	9	3	8	1	5
De informatie was in 3Di gedetailleerder dan in de referentiesituatie	5,0	1,0	0	0	1	1	5	13	7	1	3
In vergelijking met de refentiesituatie duurder het met 3Di korter om de juiste informatie te vinden.	5,3	1,0	1	0	0	0	8	3	13	2	4
Het gebruik van 3Di is makkelijker dan gebruik van de referentiesituatie	5,3	0,9	0	0	0	0	7	4	13	1	6
Ik heb een realistischer beeld gekregen van water op de straat door 3Di.	5,6	1,1	0	0	0	2	2	7	14	5	1
Ik ben voldoende geïnformeerd over de waarheidsgetrouwheid van 3Di	5,3	0,9	0	0	0	1	5	10	14	1	0
Ik weet hoe waarheidsgetrouw de referentiemethode was.	5,3	1,0	1	0	0	1	6	8	12	2	1
Ik weet door 3Di beter waarom de eindbeslissing is genomen dan in de referentiemethode.	5,2	1,2	0	0	1	0	5	3	10	1	11
De eindbeslissing is genomen op een minder intuïtieve manier dan in de referentiesituatie.	5,3	1,0	0	0	0	0	6	3	9	1	12
Ik begrijp het effect van alternatieven op de wateroverlast beter door 3Di.	5,6	1,0	1	0	1	0	3	4	19	2	1
Ik begrijp het effect van alternatieven op andere gebieden dan wateroverlast beter door 3Di.	5,4	1,1	1	0	1	1	2	6	15	2	3
Ik ben meer tevreden met de eindbeslissing door gebruik van 3Di.	5,0	0,9	1	0	0	1	5	7	7	0	10
3Di zorgt voor een hogere kwaliteit besluitvorming	5,9	0,9	0	0	0	0	2	7	13	8	1
Welke aspecten denkt u dat van belang zijn voor het probleem?	1,7	1,1	0	13	9	4	1	1	0	0	0
Overlapping	1,0	0,9	0	17	3	3	0	0	0	0	0
Welke aspecten denkt u dat van belang zijn voor de oplossing?	1,6	1,3	0	11	7	5	1	1	0	0	0
overlapping	0,9	0,9	0	10	7	1	0	0	0	0	0
Ik heb andere dan de gegeven alternatieven overwogen tijdens de workshop.	5,1	1,4	2	0	2	1	7	3	11	4	1
Ik heb details aan de alternatieven toegevoegd (ook voor zelf bedacht alternatieven).	5,2	1,6	2	1	2	0	4	5	10	4	3
Er is een samenhang tussen de gekozen sub-oplossingen (een bepaalde strategie).	5,5	0,8	4	0	0	0	3	7	15	1	1
Er was voldoende informatie beschikbaar.	5,0	1,2	0	0	2	2	3	12	11	1	0

Mist er informatie die wel mogelijk is te geven?	5,0	1,1	7	0	0	1	7	2	7	1	6
De informatie werd gedetailleerd genoeg weergegeven.	5,4	0,8	0	0	0	1	3	11	16	0	0
De tijd om de juiste informatie te vinden in 3Di was goed.	5,2	1,2	0	0	2	0	6	7	15	1	0
De moeilijkheidsgraad van de visualisatie was goed.	5,7	0,9	0	0	0	1	3	2	21	3	0
Het 3Di model is waarheidsgetrouw.	4,8	1,1	0	1	0	0	10	9	9	0	2
Ik begrijp waarom de eindbeslissing genomen is.	5,1	0,9	0	0	0	0	6	3	8	0	14
De eindbeslissing is genomen op een intuïtieve manier.	4,4	1,0	0	0	1	1	10	4	3	0	12
Ik begrijp het effect van alternatieven op de wateroverlast.	6,0	0,5	1	0	0	0	0	4	22	3	1
Ik begrijp het effect van alternatieven op andere gebieden dan wateroverlast.	5,5	0,8	1	0	0	1	2	7	17	0	3
Ik ben tevreden met de eindbeslissing.	5,1	1,1	1	0	1	0	4	6	7	1	11
Ik zou de tool aan iemand aanraden voor deze vorm van gebruik	5,8	0,8	0	0	0	1	0	8	18	4	0
Ik zou de tool aan iemand aanraden voor een andere vorm van gebruik	5,2	1,2	2	0	0	0	11	3	8	4	3

F.2. Results open questions questionnaire

Mentioned aspects Rivierenbuurt Problem	**#**	**Mentioned aspects Houtmankade Problem**	**#**
ruimtelijke inrichting	8	ondergrond	1
schade	2	grondwaterstand/wortelsterfte bomen	3
veiligheid	2	oppervlaktewater	1
bereikbaarheid	2	verharding	2
communicatie	1	maaiveldhoogte	1
drempels	1	beheersinspanning	2
onderhoud openbare ruimte	1	hoeveelheid riool	1
integraliteit	3	schaderisico's	1
afvoer	1	drempelhoogte woningen	1
verharding	3	waternet	1
winkeliers en woningen	2	openbare ruimte inrichting	2
verkeer	1	kosten	1
financiën	2	waterkwaliteit	1
communicatie tussen diensten	1	nieuwbouw/zelfbouwgroepen/parkeergaragebouw	2
leefbaarheid	1	vervanging riool	1
		politieke bereidheid	1
		communicatie	1
		landgebruik	1

Mentioned aspects Rivierenbuurt Solution	**#**	**Mentioned aspects Houtmankade Solution**	**#**
flexibel denken overheden	1	bewustwording	1
hulpdiensten	1	acceptatieniveau	1
bestuur/stadsdeel	3	financiën	1
juridische verantwoordelijkheid	1	organisatie (zelfbouwgroepen)	3
waternet	2	besluitvorming	2
inrichting openbare ruimte	5	bergend oppervlak/groen	5

financiën	1	Diameter riool/kolken/ondergrondse infrastructuur	3
verharding	2	hol wegprofiel	1
invaliden	1	hinder werkzaamheden	1
verkeer	1	openbare ruimte	2
bestemmingsplan	1	bodemgesteldheid	1
bewoners/achtertuinen	2	goeie ontwerpen	1
communicatie	1	lange termijn denken	1
voorzorgsmaatregelen/kennisontwikkeling	1	out of the box denken	1
begrip	1		
strategie	1		

Missing information according to participants
Riool gegevens / afvoer capaciteit
in/uitloop riolering
stroomrichting, integraliteit boven/ondergronds
stroomrichtingen
het zelf kunnen gebruiken
invloed riool en Amstel
paar detail voorbeelden
riolering/grondwaterstand
drempel hoogte
ook riool in systeem en afstroom grondwater
afvoer riool
riool/DWAS/HWA/volledige model (hele stad)
riool
grondwaterstanden/invloedsfeer/dijken

Eind-oplossingen workshop Rivierenbuurt
tunnel bij M.L.K park + weg verlagen + drempels
afvoeren naar miep-giesplantsoen + drempels
afvoeren naar sportplein + drempels
Eind-oplossingen workshop Houtmankade
fietstunnel westerpark + berging westerpark
berging onder spaarndammerplantsoen + groene daken + drempels
verlagen oostzaanstraat tot afvoer in zaanhof
sloot langs zaanstraat tot fietstunnel

F.3. Interpretation results for decision quality elements

element	Questionnaire (Comparison)	Value (Comparison)	Questionnaire (3Di quality)	Final processing (3Di quality)	Value (3Di quality)
decision framing - consciousness of perspectives	Door het gebruik van 3Di zie ik meer belangrijke aspecten van het probleem en de oplossing.	1 question	Welke aspecten denkt u dat van belang zijn voor het probleem?	Categorize aspects. Counting number of aspects and overlapping aspects	4 is as average. Above 4 is more overlapping aspects, below is less
alternatives - creativity and diversity of alternatives	Door gebruik van 3Di heb ik meer alternatieven overwogen.	1 question	Ik heb andere dan de gegeven alternatieven overwogen tijdens de workshop.	Difference alternatives from hand-out list.	The question as value. Differences in alternatives is apart considered, because it does not give a value per participant
alternatives - level of detail of alternatives	Door gebruik van 3Di heb ik alternatieven meer tot in detail kunnen uitwerken	1 question	Ik heb details aan de alternatieven toegevoegd (ook voor zelf bedacht alternatieven).		1 question
alternatives - coherence of alternatives	Door gebruik van 3Di is het gemakkelijker een strategie te kiezen of toepassen.	1 question	Er is een samenhang tussen de gekozen sub-oplossingen (een bepaalde strategie).	Difference sub-alternatives (coherence in final decision)	The question as value. Differences in alternatives is apart considered, because it does not give a value per participant
Information - availability of information	In vergelijking met mijn referentiesituatie was er meer informatie beschikbaar door 3Di. Door gebruik van 3Di miste ik minder informatie dan in mijn referentiesituatie.	Average 2 questions	Er was voldoende informatie beschikbaar. Mist er informatie die wel mogelijk is te geven?	The question for missing information is valued inverse, the values are therefore inversed.	Average 2 questions
Information - clarity of information	In vergelijking met de refentiesituatie duurde het met 3Di korter om de juiste informatie te vinden. Het gebruik van 3Di is makkelijker dan gebruik van de referentiesituatie	Average 2 questions	De tijd om de juiste informatie te vinden in 3Di was goed. De moeilijkheidsgraad van de visualisatie was goed.		Average 2 questions
Information - correctness and explicitness of information	Ik heb een realistischer beeld gekregen van water op de straat door 3Di. De informatie was in 3Di gedetailleerder dan in de referentiesituatie.	Average 2 questions	Het 3Di model is waarheidsgetrouw. De informatie werd gedetailleerd genoeg weergegeven.		Average 2 questions
Information - awareness of uncertainty of information	Comparison thruthfullness reference and 3Di (2 questions). Ik weet hoe waarheidsgetrouw de referentiemethode was. Ik ben voldoende geïnformeerd over de waarheidsgetrouwheid van 3Di	If both scores are equal, the value is 4. If 3Di scores 1 higher, the value is 5. If the reference is valued higher, the value is that amount lower than 4 etc.	Het 3Di model is waarheidsgetrouw.	The awareness of uncertainty of information depends on how right the participants are about the correctness. But an independent value for correctness of 3Di cannot be given. This criterium will therefore not be evaluated for 3Di.	The opinion about thruthfullness will be given as value.
Logic - logic of reasoning	Ik weet door 3Di beter waarom de eindbeslissing is genomen dan in de referentiemethode. De eindbeslissing is genomen op een minder	Less inituitive is a higher quality, so the values of these questions	Ik begrijp waarom de eindbeslissing genomen is. De eindbeslissing is genomen op een intuïtieve manier.	Inituitive is not increasing the quality, so the values for that are inversed.	Average 2 questions (while one is inversed)

	intuïtieve manier dan in de referentiesituatie.	are averaged.			
Logic - understanding of consequences of alternatives	Ik begrijp het effect van alternatieven op de wateroverlast beter door 3Di. Ik begrijp het effect van alternatieven op andere gebieden dan wateroverlast beter door 3Di.	Average 2 questions	Ik begrijp het effect van alternatieven op de wateroverlast. Ik begrijp het effect van alternatieven op andere gebieden dan wateroverlast.		Average 2 questions
commitment to action or implementation	Ik ben meer tevreden met de eindbeslissing door gebruik van 3Di.	1 question	Ik ben tevreden met de eindbeslissing.		1 question
Indicated decision quality	3Di zorgt voor een hogere kwaliteit besluitvorming	1 question	Ik zou de tool aan iemand aanraden voor deze vorm van gebruik. Ik zou de tool aan iemand aanraden voor een andere vorm van gebruik		Average 2 questions

If the average is taken of two questions, a normal answer is obtained when both questions are answered. If one question is answered with ‘not applicable’ or not answered at all, the answer for the other question is seen as average. If both questions are not answered or are answered with ‘not applicable’, the average is ‘not applicable’ or no answer. The standard deviation is calculated from the average scores. The minimum and maximum answer are obtained from the original answer.

F.4. Results per criterion

	Consciousness	Creativity alternatives	Level of detail alternatives	Coherence alternatives	Availability information	Clarity information	Correctness information	Awareness uncertainty information	Logic reasoning	Understanding consequences	Commitment	Indicated decision quality
Average comparison	5,80	5,47	4,48	5,73	5,07	5,33	5,27	4,03	5,21	5,53	5,00	5,90
Lowest	4,00	2,00	1,00	4,00	2,00	4,00	2,00	1,00	2,00	2,00	3,00	4,00
Highest	7,00	7,00	6,00	7,00	7,00	7,00	7,00	6,00	7,00	7,00	6,00	7,00
Using a model	6,14	5,50	4,86	6,00	5,36	5,50	5,13	3,50	5,70	5,69	3,75	6,86
Not using a model	5,70	5,45	4,35	5,65	4,98	5,28	5,33	4,24	5,06	5,48	5,31	5,61
Rivierenbuurt	5,80	5,63	4,85	5,93	5,18	5,57	5,28	4,25	5,50	5,63	5,36	6,20
Houtmankade	5,80	5,29	4,14	5,53	4,96	5,04	5,27	3,77	4,83	5,43	4,56	5,60
Working with water	5,74	5,52	4,45	5,65	5,00	5,43	5,31	3,83	5,26	5,52	4,94	6,00
Not working with water	6,00	5,29	4,57	6,00	5,33	5,00	5,14	5,00	5,00	5,57	5,33	5,57
Average 3Di	4,00	5,14	5,15	5,54	4,42	5,16	5,11	4,83	4,25	5,74	5,11	5,52
Lowest	3,05	2,00	1,00	4,00	2,00	2,00	1,00	1,00	2,00	3,00	2,00	3,00
Highest	5,55	7,00	7,00	7,00	7,00	7,00	6,00	6,00	6,00	7,00	7,00	7,00
Using a model	4,61	5,38	5,63	5,50	4,25	4,63	5,38	5,43	3,90	5,81	4,75	6,13
Not using a model	3,79	5,05	4,94	5,55	4,48	5,35	5,02	4,64	4,37	5,71	5,20	5,30
Rivierenbuurt	4,02	5,33	5,36	5,92	4,47	5,25	5,41	5,36	4,21	5,93	5,30	5,75
Houtmankade	3,98	4,92	4,92	5,21	4,37	5,07	4,80	4,33	4,31	5,54	4,89	5,27
Working with water	4,07	5,10	5,10	5,58	4,42	5,13	5,19	4,91	4,15	5,82	5,25	5,63
Not working with water	3,76	5,29	5,33	5,43	4,43	5,29	4,86	4,57	4,83	5,50	4,33	5,14